THE UNIVERSITY OF ALBERTA

LATE CENOZOIC ALKALINE VOLCANICS OF THE LEVEL MOUNTAIN
RANGE, NORTHWESTERN BRITISH COLUMBIA: GEOLOGY, PETROLOGY AND
PALEOMAGNETISM

by

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ABSTRACT

Level Mountain is a Late Cenozoic shield volcano
located near 131°20'W,58°31'N in the Stikine Volcanic Belt
of northern British Columbia. The volcanic plateau with an
average elevation of 4500',(1372m), is younger than Upper
Miocene in age and is comprised of up to four sequences of
alkali basalt and ankaramite flows and tuffs. The central
region of peaks and ridges rises to a maximum elevation of
7200',(2195m), and has a repetitive bimodal distribution of
alkali basalt and peralkaline salic lavas and tuffs that
spans the period from 4.5 million years b.p. to recent
times. Feeble basaltic vents with spatter, bombs and scoria
apparently postdate continental glaciation. A paleomagnetic
study on two stratigraphic sections that span the entire
range of volcanism samples the earth's major polarity
reversals for the past 6 MY.

Petrochemically the lavas belong to the sodic alkali
basalt series and are of continental affinity. Oxygen
isotope values near $5.6^o/_{oo}\delta^{18}O$ SMOW have been measured for
unaltered rocks including basalts, salics, and ultramafic
inclusions. This would seem to indicate that the mantle
under northwestern British Columbia is normal with respect
to oxygen and that the Level Mountain magmas are mantle
derived. Corroborating evidence is available from the whole
rock strontium isotope studies which show a total range of
$^{87}Sr/^{86}Sr$ from .7025 to .7071. The presence of basic and

salic, undersaturated and ovesaturated, peralkaline and metaluminous rocks attests to the complexity of petrogenetic processes at Level Mountain. Although the two volumetrically important lava types appear to be primary and mantle derived, the presence of some rhyolites enriched in ^{18}O, granitic gneiss inclusions in basalts and tristanites and great variation in whole rock lead isotope ratios are probably all indicative of some degree of interaction between magmas and crustal rocks. Major and trace element geochemical variations and mineralogy indicate an upper mantle origin at shallower than 15 kbar pressure from an undersaturated ultramafic source that possessed an abundance of alkalis and incompatible elements. The mineralogy and chemistry of the major rock types indicate conditions of low oxygen fugacity and a dry gas phase composition for both peralkaline flows and basalts. The field relations of some comendite flows implies fluid behavior and seems to indicate a viscosity two to three orders of magnitude lower than would be predicted on the basis of silica content and whole rock chemistry. This could be partially reconciled if the gas phase had been halogen rich and dry.

Calculations of the volume and energetics of the volcanism of the Stikine Belt indicate that less than 15% of the modern heat flow is necessary to maintain the levels of volcanicity since Pliocene times.

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CHAPTER 8. CRYSTALLIZATION AND MELTING EXPERIMENTS AT ONE ATMOSPHERE TOTAL PRESSURE ON SELECTED ROCKS FROM LEVEL MOUNTAIN

INTRODUCTION

A series of more than one hundred reconnaissance experiments was conducted to determine the crystallization behavior of fourteen Level Mountain lavas. Six of the lavas were peralkaline salics and five were basaltic. The remaining three were an alkaline trachyte, a tristanite and a phonolite. Additionally, thirty-five experiments were conducted to determine the solidus temperatures of six xenoliths of mafic and ultramafic composition. For these experiments, the conditions covered the temperature interval from 800°C to 1300°C with the principle range of oxygen fugacities between the FMQ and MW buffers. Twenty-nine experiments were additionally performed under more oxidizing conditions to assess the effect of variable fO_2. For the most part these experiments were rock-air buffered somewhere between FMQ and HM.

PREVIOUS WORK. CRYSTALLIZATION AND MELTING RELATIONSHIPS OF PERALKALINE ROCKS

A number of studies have been conducted on the melting characteristics of peralkaline rocks. Rather different behavior has been demonstrated for plutonic versus volcanic

undersaturated peralkaline rocks (agpaites).[1] The most
prominent initial observation from experimental work was
that agpaites had much longer melting intervals than common
rock types (Piotrowski and Edgar, 1970; Sood et al, 1970).
The large liquidus - solidus interval has been attributed in
part to peralkalinity and in part to high concentrations of
uncommon or incompatible geochemical elements (Ti, Zr, REE,
Fe^{3+}, Cl). The halogens and water in these systems may be
preferentially retained in the melt, thus affecting an
abnormal depression of the solidus, particularly at higher
pressures (Anderson, 1974; Manning, 1981). Edgar and Parker
(1974) successfully verified this hypothesis for eight
crystalline rocks, four plutonic and four volcanic. The
melting intervals were typically greater for the plutonic
rocks than for the volcanics of similar composition.
Presumably this was due to differences in previous cooling
history of samples versus incorporation of halogens into
crystals and the glass. The experiments reported by
Piotrowski and Edgar and by Edgar and Parker were conducted
at either one atmosphere or at one kilobar water pressure,
unbuffered. Their two-point hydrous liquidus curves appear
to be normal, with negative slopes ($dP/dT<0$). in the
determination of the liquidus for the crystalline samples,

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[1] Peralkaline plutonic rocks have been termed agpaites
(Sorenson, 1970). They are characterized by a peralkalinity
index greater than unity (Ac±Ns in the norm), high
concentrations of Fe, Ti, Zr, REE, F, Cl and unusual
mineralogy which may include eudialite, rinkite,
rosenbuschite. Typical occurences of these rocks are found
at Khibina,Kola and Ilimaussaq.

For the four Tenerife phonolites the one-atmosphere liquidus temperature ranged from 1030° to 1200°C. The crystallization sequence at one atmosphere was feldspar followed by nepheline then amphibole. When pH_2O is low, clinopyroxene may crystallize before amphibole or in place of amphibole. The order of appearance of clinopyroxene on the liquidus is quite variable. The phonolites were of the mildly peralkaline type with A.I. ranging from 1.03 to 1.19. Melting intervals determined for three of the phonolites ranged from 305°C to 475°C.

The silica oversaturated peralkaline system has been studied experimentally by Bailey et al (1974). Their studies were anhydrous but unbuffered and conducted over a range of pressures from one atmosphere to approximately 1.5 kilobar. Their samples were pantellerites and pantelleritic trachytes from East Africa (Menghi, Longonot, Eburru). The work of Bailey et al (1974) was done on very peralkaline compositions with A.I. = 1.38 to 2.18. While the solidus temperature was not determined, the liquidus temperature showed a strong linear decrease with increasing peralkalinity. For all compositions studied, plagioclase was the silicate liquidus phase to one kilobar. Sample 83, Eburru Pantellerite, also had phenocryst quartz at one kilobar. There was something noteworthy and rather unusual about the liquidus curves reported in Bailey et al (1974) and Bailey and Cooper (1979), see Figure 8-1. The boundary of the liquidus line in PT space, and also the

Figure 8-1.

Liquidus curves for peralkaline trachytes (KL4, KE4) and more siliceous pantellerites (KE12, KW5) taken from Bailey et al (1974). As pressure increases the liquidus temperature goes through a minimum, then increases linearly to about 5kbar. Depending on the ascent path, such melts could develop considerable superheat. Note convergence of liquidus curves to higher P and T.
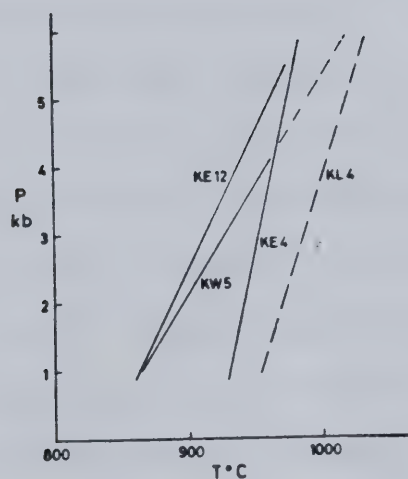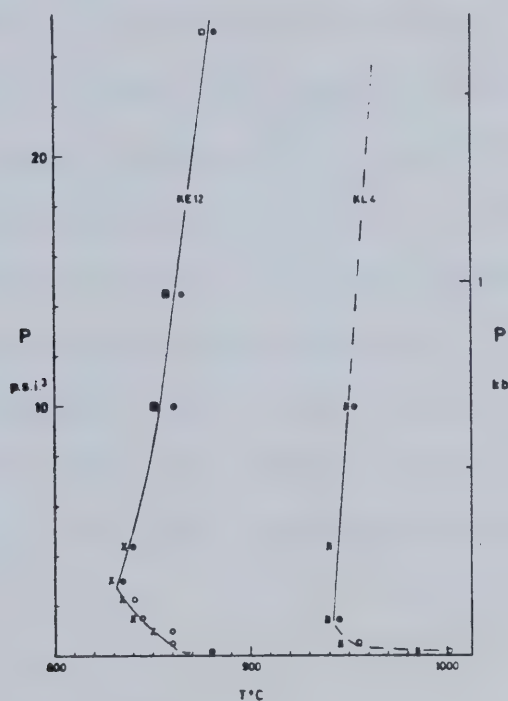
crystallization surfaces for alkali feldspar and quartz, are concave to higher temperatures with a temperature minimum at about 0.3 kilobar. If this is indeed the case, a peralkaline magma could possibly acquire some degree of superheat upon ascent (Waldbaum, 1971; Marsh and Kantha, 1978). Partially resorbed alkali feldspar and quartz phenocrysts are a common feature of sparsely crystalline and glassy peralkaline salic lavas. Comendites and pantellerites typically display flow morphologies characteristic of fluid behavior, which contrasts with the more viscous nature of calc-alkaline rhyolites of similar SiO_2 content (Shaw, 1973; Schmincke, 1974). Both of these observations might arise from such a heat input implied by the liquidus determinations of Bailey et al (1974).

EXPERIMENTAL TECHNIQUES

Experiments were cinducted on the Deltech furnace under controlled fO_2 conditions achieved by the use of known mixtures of CO and CO_2. The samples, either pressed mineral powder briquettes or glasses quenched from 1300°C, were sintered onto a Pt wire loop and suspended in the thermally uniform position of the furnace after the technique of Donaldson et al (1975). Experiment durations were generally one to three hours. Rapid quenching was achieved by severing the suspension wires so that the sample fell into a mercury filled receptacle at the base of the furnace.

RESULTS

The results of the melting experiments on Level Mountain lavas are summarized as a series of bar graphs in Figure 8-2. The basaltic lavas had the crystallization sequence oxide, olivine, clinopyroxene, plagioclase. The crystallization data is summarized in Table 8-1. An oxide phase crystallized above 1260°C. Compositionally these were magnetite - ulvospinel solid solutions. Forsterite-rich olivine was the first silicate phase on the liquidus between 1250°C and 1265°C. With the exception of Ne-normative hawaiite, 8/25-50/6397, diopsidic clinopyroxene appeared as the second silicate phase. The clinopyroxene liquidus fell in the interval 1250° to 1165°C. Towards the lower temperature end of this range an intermediate plagioclase, labradorite to andesine composition, was on the liquidus. This compares favorably with the one atmosphere crystallization experiments conducted on alkali basalt by Thompson and Flower (1971) and Duke (1974). Residual phases such as alkali feldspar and nepheline did not appear until near the solidus, between 1100°C and 1050°C. Often two distinct forms were present in the crystallized phases. While the high temperature titanomagnetites tended to be well formed cubes or octahedra, a second dendritic or quench textured magnetite formed particularly in the runs quenched from the lower temperature range of the melting interval. Olivines formed as discreet prisms of equant to acicular habit, while clinopyroxenes crystallized as blades both

Figure 8-2.

Buffered crystallization sequences and melting intervals for Level Mountain lavas. Comendites: (1) 9/2-99 and (2) 8/25-54/6345; Pantellerites: (3) 25/5e and (4) 8/5-8/5150; Comenditic Trachyte: (5) 24/2 o/c and (6) 25/7; Trachyte: (7) 24/hi; Tristanite: (8) LMIIIA; Phonolite: (9) LMI20i; Hawaiite: (10) 8/25-50/6397; Alkali Basalts: (11) and (14); Ankaramites: (12) and (13). T range of experiments indicated by length of line. Highest T occurrence of a mineral plotted as appropriate symbol.
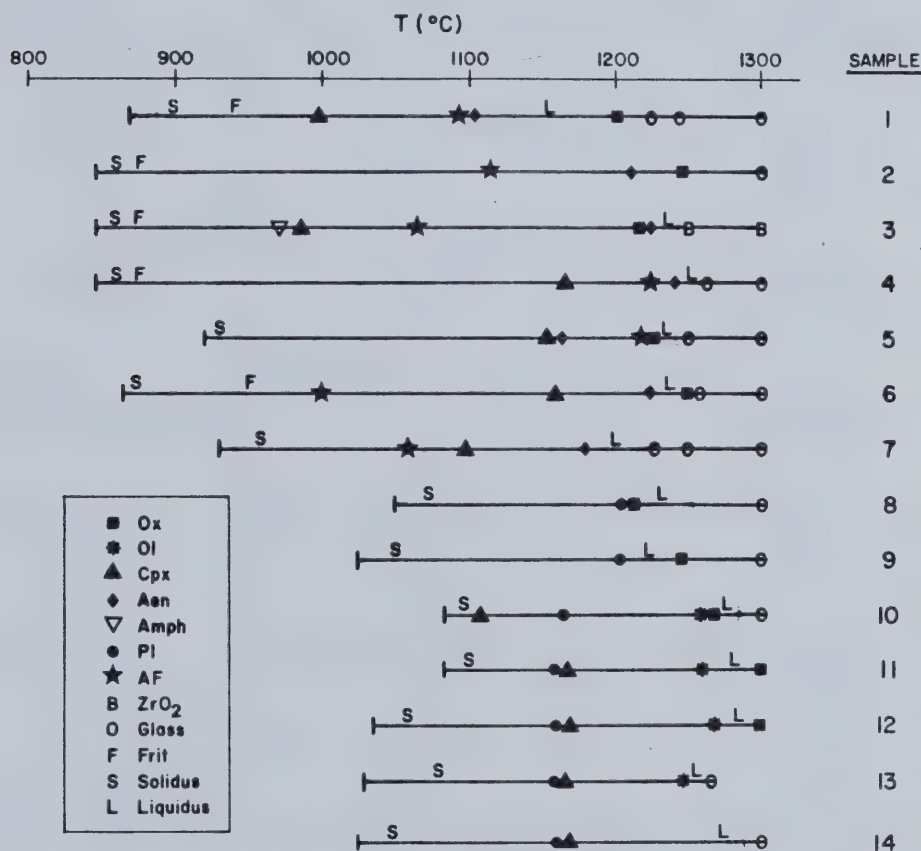
Table 8-1   Liquidus and Solidus Data for Basic and
             Intermediate Lavas from Level Mountain

Sample	TL°C	T_s°C	T_m°	TL°C Calc*
LMI20i phonolite	1225 ±20	1050 ±25	175 ±45	1173 pl 1086 cpx 1006 ol
LMIIIA tristanite	1230 ±25	1041 ±31	189 ±56	1364 pl 1050 cpx 876 ol
8/25-59/6397 hawaiite	1270 ±15	1080 ± 7	190 ±22	1165 ol 1140 pl 1135 cpx
PAP Alkali basalt	1275 ±15	1100 ±15	175 ±30	1210 ol 1205 cpx 1173 pl
O1 Ankaramite	1250 ±10	1062 ±12	188 ±22	1327 ol 1230 cpx 1048 pl
h ankaramite	1255 ±10	1092 ± 5	163 ±15	1264 pl 1171 ol 1165 cpx
29/1-f early hawaiite	1275 ±13	1083 ±73	192 ±86	——————

* French (1971)

singly and as feathery, quench textured aggregates. Plagioclase crystallized both as blades and dovetail prisms. The crystallization sequences found experimentally correspond to the natural behavior inferred from the petography of the respective lavas; however, the actual crystal forms may differ due to kinetic effects (Donaldson, 1976). The average measured silicate liquidus temperature for five Level Mountain basalts was 1265°±5°C, with a corresponding average solidus of 1083°±6°C. The average of the five basalt melting intervals was 182°±5°C.

The crystallization sequence of the phonolite and tristanite were oxide, plagioclase, alkali feldspar, clinopyroxene. The oxide appeared between 1212°C and 1247°C. Plagioclase and andesine to oligoclase composition appeared above 1205°C with the silicate liquidus temperatures for phonolite and tristanite set at 1225°±20° and 1230°±25° accordingly. The averages for these two intermediate lavas are liquidus temperature: 1228°C±3°, solidus temperature: 1045°C±5° and melting interval: 183°C±7°. The liquidus and solidus are marginally lower than for the basalts and the melting interval is the same.

The crystallization behavior of the salic lavas is summarized in Figure 8-2 with temperature data listed in Table 8-2. The average silicate liquidus temperature for the seven Level Mountain lavas was 1216° ± 13°C. The average salic solidus was 894°±15°C and the average melting interval was 308°±22°C. The largest melting range observed was for

Table 8-2   Liquidus and Solidus Data for Salic Lavas
             From Level Mountain

Sample	TL°C	T_S°C	T_m°	TL°C Calc*
24/1 hi trachyte	1190 ±10	965 ± 35	225 ±45	1189 1050 995
24/2 o/c	1235 ±10	930 ± 10	305 ±20	———
25/5e pantellerite	1235 ±10	862 ± 13	273 ±23	1149 1071 978
25/7	1233 ± 7	875 ± 10	358 ±17	1138 1027 986
9/2-99 comendite	1155 ±50	900 ± 30	255 ±80	1150 1056 986
8/5-8/5150 pantellerite	1250 ±10	862 ± 13	388 ±23	1147 1044 962
28/25-54/6345 comendite	1215 ±10	862 ± 13	353 ±23	1131 1060 994

* French (1971) Plagioclase; Clinopyroxene; Olivine

pantellerite 8/5 -8/5150 (388°±23°C). The liquidus

determinations are somewhat higher than previously reported

(Bailey et al, 1979). This is presumably due to the present

study being anhydrous and buffered at lower fO_2. The long

melting intervals are comparable to data on peralkaline

phonolites and plutonics reported by Edgar and Parker

(1974).

Aenigmatite was the first silicate to crystallize for

six out of seven samples under the conditions of low fO_2.

The aenigmatite crystallized as a deep reddish brown pseudo-

hexagonal thin platelets both singly and in "squadron

formation", where platelets in small regions of the glass

were all in parallel orientation, see plates 8-1 and 8-2.

This presumably indicates regions of intermediate to long

range order in the glass. The aenigmatite may be preceeded

by an oxide phase, although a reaction is usually indicated

due to disappearance of the oxide at and below the

temperature of aenigmatite crystallization. At the silicate

liquidus temperature the oxide reacts with the peralkaline

component (Ns) of the melt to form aenigmatite. The

incongruent melting of aenigmatite has previously been

reported (Lindsley, 1971; Lindsley and Haggerty, 1971).

Incongruent melting has also been noted for acmite (Bailey,

1969). Aenigmatite is followed by intermediate to potassic

alkali feldspar and sodic hedenbergite in either order. The

pyroxenes are prismatic while the feldspars are either

lathlike, in the upper end of the melting range, or a matte

Plate 8-1.
Photomicrograph (P.P.L., 340x240microns) of a
crystallization experiment on peralkaline trachyte
8/5-8/5150. Aenigmatite reddish brown pseudohexagonal
platelets occur on the liquidus for $T-fO_2$ conditions between
M-W and FMQ.

Plate 8-2.

Photomicrograph (P.P.L., 68x48microns) of a crystallization experiment on pantellerite 25/5e at 1201°C and log fO_2 = -8.78. Pseudohexagonal brown aenigmatite is followed at slightly lower temperatures by the crystallization of an oxide phase. Possibly having crossed the boundary curve for $Aen + O_2 = TiMt + Nds + SiO_2$ as a result of the specific fO_2 conditions or early aenigmatite crystallization having lowered the peralkalinity sufficiently to shift the equilibria.

of microlites near the solidus. A bluish alkali amphibole, presumably riebeckite, was observed in one charge of pantellerite (25/5e) and in the mid-melting range of some of the earlier unbuffered experiments. The unbuffered experiments had slightly lower liquidus temperatures (average of five determinations $1138 \pm 35°C$) with the sequence oxide, alkali feldspar, clinopyroxene, alkali amphibole or oxide, aenigmatite, alkali feldspar. In considering just the latter low fO_2 experiment, there is a great deal of variation in crystallization sequence and in temperature intervals between sequential appearance of the various silicate phases. This degree of variability in the crystallization behavior of these seven samples would not be expected from the small degree of compositional variation in the major element contents of these lavas.

CHAPTER 9. THE PHYSICAL BEHAVIOR OF LEVEL MOUNTAIN LAVAS

VISCOSITIES: ESTIMATED AND EXPERIMENTAL⁻

Theoretical Viscosity Calculations

' For lavas of known composition, viscosities have been
predicted according to the model of Shaw (1972). These
calculations were performed using a fortran computer
programme supplied by J. Nicholls to give a log-linear
expression of the form:

ln n(pascal-sec) = A/T°K - B

which corresponds to newtonian behavior. This type of
relationship has been shown to be valid above the liquidus
temperature while below the liquidus the viscosities
increase more rapidly due to the presence of crystals and
the behavior is no longer newtonian (Shaw, 1969; Scarfe,
1973; Murase and McBirney, 1973). The conversion from SI to
cgs units, which have been conventionally used is:

10 e exp(ln n(pascal-sec)) = n(poise)

To characterize the expected variation in viscosity for
Level Mountain lavas and to compare it to other British
Columbia lavas, the theoretical anhydrous viscosity has been
calculated at 1300°C. The range of predicted viscosities is
tabulated as a function of rock type for Level Mountain and
other Cordilleran lavas, table 9-1. The lowest predicted

' Throughgout this chapter the symbol n is used to denote
viscosity.

Table 9-1 Range of Predicted Viscosities as a Function of Rock Type

Rock Type	ln (pascal-sec)[1]	median
Alkali Basalts and Ankaramite	0.4 to 2.4	1.7
Hawaiites	1.8 to 3.4	2.7
Mugearites, Benmoreites and Phonolites	4.2 to 6.4	5.3
Trachytes and Tristanites	6.6 to 8.8	7.3
Comendites and Rhyolites	9.0 to 10.8	9.7

1. Viscosity calculated from chemical analysis on an anhydrous basis at 1300°C after the method of Shaw, 1972.

viscosities are for ankaramites and other basalts. Melts of basaltic composition have a high proportion of network modifier cations and a less polymerized polyanionic melt framework (Scarfe, 1973, 1977; Scarfe et al, 1979; Mysen et al, 1980). The highest predicted viscosities are for metaluminous rhyolites with comendites being slightly lower. The samples from Edziza and other late Cenozoic lavas in British Columbia display the same range of variation as seen at Level Mountain. For the purposes of comparison, all of these viscosities were calculated using dry chemical analyses. The effect of water is to de-polymerize the silicate melt by increasing the proportion of non-bridging oxygens. The calculated effect of this depolymerization for these relatively dry alkaline lavas is generally less than a few percent lowering in ln n and the inaccuracy introduced by comparing lavas at a single temperature of 1300°C should outweigh this. The value of 1300°C was chosen to be above, but close to, the liquidus for all of the alkaline lavas. This is about 35°C above the average basalt liquidus and 85°C above the average salic liquidus.

Experimental Viscosity Determinations

Three rocks were chosen to represent the basalt to comendite sequence at Level Mountain: hawaiite (8/25 - 50/6397), alkali basalt (PAP), and comendite (8/25 - 54/6345). For chemical analyses please see chapter on petrochemistry. Rock powders (which passed the 325 mesh screen) were prepared from these specimens. Experimental

work was performed by C.M. Scarfe at Sheffield University
(Scarfe and Hamilton, 1980). Glasses free from bubbles and
crystals were fused from whole rock powders, under reducing
conditions, in a gas furnace at 1400° - 1600° , for two
hours. Fusions were performed in alumina crucibles and the
liquid was poured into a steel mold to make a glass slug
whose diameter matched the internal dimensions of the outer
cylinder of a concentric cylinder viscometer (Scarfe 1977).
Under measurement conditions, the 8cc glass slug filled the
cavity between the inner and outer platinum cylinders of the
viscometer. During a measurement, shear across the silicate
liquid transmits torque to the inner cylinder which results
in an angular displacement. The displacement is recorded as
a light spot deflection on a linear scale. At constant
temperature, there is a linear relationship between rotation
speed of the outer cylinder and angular displacement of the
inner cylinder. This corresponds to a plot of shear stress
versus shear rate, which for newtonian fluids is a straight
line through the origin. All experimental determinations
were performed in air. Viscosities are considered accurate
to ±5°C in the range 1200°C to 1400°C. Starting glasses for
the hawaiite sample were prepared under both oxidizing and
reducing conditions. The resulting difference in measured
viscosities was very small, with the reduced aliquot being
slightly less viscous at any temperature. This could be
related to enhancing the behavior of Fe as a network
modifier under reducing conditions (Fe^{2+} rather than Fe^{3+}).

Results for the three Level Mountain lavas are presented in Figure 9-1. The apparatus was calibrated using NBS Standard 710, a soda-lime silica glass, for which the viscosity-temperature relationship is accurately known. Curves through experimental points are fit by hand. Dashed lines correspond to theoretically predicted viscosities. Viscosities calculated using the method of Shaw (1972) agree with experimental determinations to within 0.25 log units, with the predicted values being lower than measured values in all cases. A linear relationship exists between the logarithm of the viscosity and the reciprocal absolute temperature in the range 1300° to 1400°C. The temperature dependence of the viscosity can be described by an Arrhenius relationship of the form $n = n_0 e \exp(En/RT)$ where n_0 is constant for a given melt, and En is the activation energy for viscous flow. Activation energies for the Level Mountain lavas are in the range 98 kcal/mol for the comendite to 54 kcal/mol for the hawaiite. At any temperature above the liquidus the viscosity of the comendite is about three orders of magnitude greater than the basalts. For example, at 1300°C the comendite has $\ln n = 5.3$ poise as compared with $\ln n = 2.05$ and 2.60 for the basalts; ($\ln n = 9.4$, 3.6, 2.3 pascal - sec respectively). Despite the fact that theoretical and experimental data agree in predicting a high viscosity for comendite, this does not account for the apparent fluid nature of comendite flows at some locations on Level Mountain. Both experimental and theoretical data

Figure 9-1.
Plot of reciprocal absolute temperature versus log viscosity
(in poise) comparing experimentally determined viscosities
to Shaw model predictions, taken from Scarfe and Hamilton
(1980).
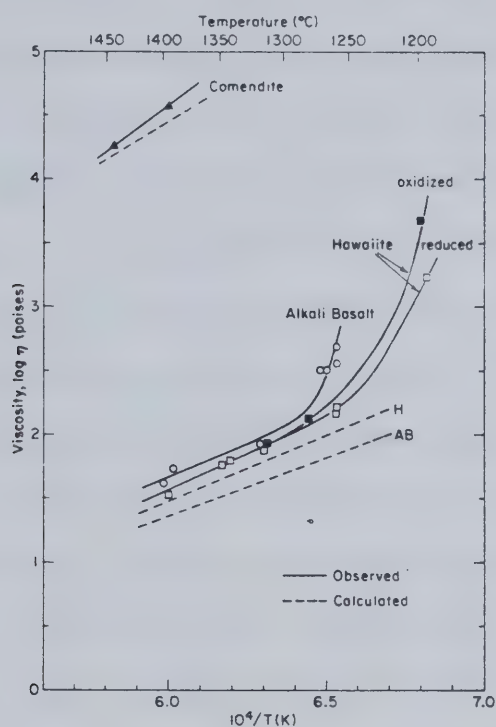
relate to a degassed dry sample. Under natural conditions of emplacement and extrusion, dissolved volatiles in the comendite melt, particulartily fluorine and chlorine (Bailey and MacDonald, 1975; Scarfe, 1977), may have reduced viscosities considerably below 10^5 poise. Degassing could eventually increase viscosity to the point where flow will cease (Nash and Evans, 1977). The other possibility is that comendite may acquire some degree of superheat (Marsh and Kantha, 1978) due to a peculiarity of the liquidus geometry in PT space and ascent path (Bailey et al, 1974). The only problem is that for the viscosity-temperature relationships presented here, an extrusion temperature of 1500°C would still give a viscosity too high to explain fluid features, lava tubes, thin flows (less than 3m thick), long low volume flows, lineations, flow folds and thin dykes (less than 1m thick) which have been observed in the field. Comendites should have a more polymerized melt than basalts due to high silica contents, high $R=(Si+Al)/O$ (atomic) (Shaw, 1965; 1972) and low ratios of non bridging oxygens to tetrahedrally coordinated cations, principally Si and Al (NBO/T, Mysen et al, 1980). The precise effects of high $Fe/(Si + Al)$, $(Na + K)$, (Na/K) halogen content, and eruptive temperatures, as compared with these values in calc-alkaline rhyolites of similar silica contents, are unknown; however, all of these characteristics could contribute to a lower viscosity (Schmincke, 1974). Also there is probably a pressure effect which contributes to decreasing the

viscosity of salic melts due to a collapse of their
one-atmosphere 3D polymer structure at higher pressures
(Virgo et al, 1979). Characterizing the viscosities for the
Level Mountain lavas is important to an understanding of
their flow properties, extrusion rates and nodule transport.

CONSTRAINTS ON THE RISE TIME OF LEVEL MOUNTAIN LAVAS

Introduction

This section is devoted to placing physical and fluid
mechanical constraints on the rise times and emplacement
velocities of the various lava types found in the alkaline
association at Level Mountain. Settling calculations have
been performed for selected flow-nodule pairs. Some diapiric
rise and heat transfer calculations are also presented. The
data used in this section comes from a variety of places.
Liquidus and solidus determinations were made on glassy
charges suspended in a Deltech vertical tube quench furnace
equipped for gas mixing. Oxygen fugacity was controlled to
lie between FMQ and MW buffers using mixtures of CO and CO_2
after Dienes et al (1974). Viscosities are calculated at the
liquidus and, when available, experimental values are used.
Due to the dry nature of these lavas (see chapter on
petrochemistry), the effect of wet versus dry viscosities is
small, especially when compared to other assumptions made in
model calculations. All of the liquidus data, eleven values
covering the entire range of lava compositions, were plotted

as $10^4/T°K$ versus ln n(SI units) to give the following

linear relationship at the liquidus:

ln n = 18.75 ($10^4/T°K$)-117.91

with a coefficient of determination of r^2= 0.79 as

determined by least squares linear regression. This

empirical expression was used along with the Shaw equation

ln n = A/T°K - B

for each lava to predict liquidus temperature and viscosity

where such data was not otherwise available. Reasonable

liquidus estimates were also obtained using this expression

and other B.C. alkaline lavas, the McKinney basalt, and some

calc-alkaline andesites as well. It is conceivable that an

expression relating viscosity and temperature should exist

for a given volcano. This could be due to the mechanism of

magma genesis for a related suite or perhaps due to the

effect of common plumbing. Estimates of liquidus temperature

and viscosity could also be made by comparison with other

lavas without recourse to speculative and empirical

expressions. The determination of the significance of this

type of expression would require further research with

additional data on viscosity and liquidus temperatures. The

rational for using such empirical calculations on Level

Mountain lavas was to be able to use values for actual host

lava-nodule pairs.

Xenolith densities were analytically determined using a

weight and volume displacement technique. Lava densities

were calculated at the liquidus temperature after the method

of Bottinga and Weill (1970). The Bingham model of Sparks,
Pinkerton, and MacDonald (1977) was calculated using their
empirical graphs and SI units. Other calculations were done
for convenience in cgs units.

Nodule Transport and the Ascent of Magmas

The majority of lava flows on Level Mountain are
aphyric to fine grained and relatively free of phenocrysts.
Newtonian flow models should be adequate for these lavas,
however Sparks et al(1977) made a case for phenocryst laden
alkaline lavas behaving as a Bingham fluid. It is
conceivable that up to several flow volumes of alkali magma
could be transported through the crust as crustal rich
diapirs. Information relating to the physical properties of
lavas used in model ascent calculations is presented in
Table 9-2.

Petrographic and field relations suggest that most
lavas were at or near their liquidus temperature at the time
of eruption. Pleistocene basalts from Meszah Peak contain
xenoliths of anorthositic gneiss, troctolite and gabbro. Of
these the troctolite and gabbro are considerably denser than
their host flow. Similar basalts of the adjacent Stikine
canyon occasionally contain lherzolite nodules (Littlejohn
and Greenwood, 1974). At three locations on Level Mountain
peralkaline trachytes were found to contain armoured nodules
of ultramafic composition and a positive density contrast
with their host flows. A two meter wide tristanite dyke
contained 5 cm long gneiss fragments with a positive density

Table 9-2. Physical Properties of Level Mountain Lavas

Sample #	Rock Type	Phenocrysts	Liquidus T°C	Solidus T°C	Density** (at liquidus) g/cc	Liquidus Viscosity*** Log (poise) Predicted	Measured
8/25-54/6345	Comendite	None (Obsidian)	1215° ± 10°	862° ± 13°	2.34	5.61	5.77
8/6-12	Comenditic Trachyte	Anorthoclase	1200°	-----	2.38	5.07	-----
8/16-44/6250	Tristanite	Andesine, Barkevikite	1231°	-----	2.36	4.01	-----
8/5-8/5150	Paralkaline Trachyte	Anorthoclase, Sodic Ferrohedenbergite	1250° ± 10°	862° ± 13°	2.36	3.94	-----
PAP	Alkali Basalt	Forsterite	1275° ± 15°	1100° ± 15°	2.63	1.67	2.23
8/25-54/6397	Hawaiite	Labradorite	1270° ± 15°	1080° ± 7°	2.71	1.99	2.17
Hypothetical Lova	Alkali Basalt		1255°		2.70	1.00	

** Calculated after model of Bottinga & Weill (1970)
*** Calculated after model of Shaw (1972)
(Viscosities and densities are calculated using water+ of chemical analyses where any was present).

contrast. Further description of these nodule flow pairs is presented in Table 9-3 and in the chapter on petrography.

The existence of xenolith fragments in certain flows places two constraints on the rise times of these magmas. Where the nodule density is greater than the host lava and the nodule is sufficiently large, a slow ascent velocity would permit the nodule to settle out. If the solidus temperature of the nodule is below the liquidus temperature of the host magma, as it appears to be for most examples given here, the nodule should react, melt and possibly disaggregate. The rates of these phenomena depend on nodule size, relative thermal conductivities, grain size, fabric, chemical diffusivities and heat capacities of nodule and melt, as well as on the melt viscosity and flow regime. For the nodules to arrive intact at the surface, their residence time in the melt must be short enough to prevent either settling out or destruction.

For flow models involving a viscous compressible fluid and low concentration of spherical particles, the settling behavior changes as a function of frictional drag and Reynolds number. The Reynolds number is given by $Re=(ZrVe/n)$ (Bird, Stewart and Lightfoot, 1962). For $Re \leq 1.0$ the frictional drag is effectively a linear asympotic function of Re and the Stoke's Settling Law behavior is valid. For intermediate Re (1.0 to 1000.0) the relationship is a power law, where the friction factor (f) is given by f= 1.85Re exp(-0.6), reflecting the existence of a turbulent

Table 9-3. Characteristics of Xenoliths from Lavas of the Level Mountain Formation

Sample #	Rock Type	Model Phases	T°C Solidus[*]	(g/cc STP)[*]	Max Size(cm)	Most Flow	Relationship
Level Mountain:							
MPM	Troctolite	Plag-ol-Cpx-Opq-Ap	1086°±8°	3.13	15 cm	Hawalite 8/25-50/6397	CPX in Reaction W/Melt PLAG Partially Resorbed
8/6-12 N	Ultramafic	Cpx-Amph-Plag-Ne-Opg-Phlog	1078°±5	2.53	10 cm	Comenditic Trachyte 8/6-12/5290	nodules armoured by glassy reaction rinds
8/16-44 I	Gneiss	Plag-A.Flds.-Q-Amph-Opq	1080°±40	2.66	5 cm	Tristanite 8/16-44/6250	no Petrographic sign of melting
Heart Peaks:							
HP13 A	Essexite	Plag-cpx-ol-Amph-Opq	1085°±75	2.85	> 10 cm	Hawalite ?	no petrographic sign of melting. Sample from J. Casey
Telegraph Creek:							
TCL 1004-41	Lherzolite	ol-cpx-Cpx-Sp	1210°±22°**	3.37	5 cm	Alkali Basalt	no petrographic sign of melting. Sample from H.J. Greenwood
Hypothetical BC Lava	Lherzolite	ol-Opx-Cpx-Sp	1245°	3.3	3 cm	Alkali Basalt	CPX in Reaction W/Melt

* Hamilton 1980
* This solidus determination is comparable to the 1 bar data of Kushiro et al 1968 of 1200±5 & 1250±5 & Scarfe et al (1972) 1215±10

flow around the equator and in the lee of the particle. For high Re the friction is nearly independent f = 0.44 and the type of settling is in keeping with Newton's Law. The cutoff of Re = 2000 marks the onset of turbulent flow. Particle Reynold's numbers for relatively aphyric melts are typically smaller than 10^{-5} for salic compositions and between 2×10^{-1} and 2×10^{1} for basalts. For these crystal and nodule poor cases Stoke's law settling behavior should be reasonably valid. The greatest uncertainty is not the choice of the settling law, but the assumptions of viscosity and density contrast. For multiphase flow of crystal and xenolith mushes, the disperse particle theory no longer applies and particle boundary layers and particle interactive forces come into play. An alternate way of stating this is that in phenocryst laden melts, there is significant crystal-crystal interaction which impedes flow. Bingham model ascent rates have been calculated for the Level Mountain examples according to the models of Sparks et al (1977). For the basaltic magmas a rapid ascent time is still implied. The Bingham model is not very informative when applied to the salic magmas. The minimum ascent velocities for nodule transport, rather than settling, imply maximum rise times on the order of tens of thousands of years. Upon consideration of cooling and crystallization processes and thermal conductivities of the materials in question, this is sufficiently long to cool salic magams by conduction alone. If ascent were this slow, plutonism rather then volcanism

would have occurred.

The model of Takeuchi et al (1972) assumes buoyant rise of melts through a lithosphere of greater density. In their model the minimum velocity for magma rise is given by

$$V = \Delta\rho g d^2 / 12n,$$

where d is the characteristic dimension of the conduit. These calculations have also been presented in Table 9-4 using an hypothetical conduit dimension of 10m, which is typical of high level vents on Level Mountain, and an assumed crustal density of 2.9g/cm^3, after the crustal model for the Intermontane Belt in Southern B.C. (Keen and Hyndman, 1979). Again the assumptions regarding geometry and viscosity have far greater effects than actual magnitude of density contrast. In all cases this buoyant magma rise model predicts velocities that are orders of magnitude faster than the minimum velocity limits set by nodule transport. This model presupposes a magma-filled conduit extending through the crust. The driving force is the magmastatic head (difference in lithostatic and magmastatic pressure at depth). For basalts this magmastatic head may be as high as a few kilobars (Maaloe, 1973). The model does not account for frictional effects or the pressure required to hold the conduit open. All limitations considered, this model should put a maximum constraint on ascent velocity. In this case the velocities calculated for the hawaiite and the "typical basalt" are 20 to 30% of the expected seismic velocities (Vp) in the crust. Velocities of this magnitude are also

Table 9-4. Model Ascent Velocities and Rise Times for Level Mountain Lavas

Sample#	Rock Type	Re	Newtonian Stokes	Bingham	r=10m Takeuchi	Maximum Residence Time (Days) Nodule Melting
8/25-50/6397	Hawaiite 30km	21.92	52.7;34.3,33.0 (1 day)	2.78×10^{-2} (3.4 yr)	1.67×10^{5} (18 sec)	(4.52×10^{-1}) 75.00 day
8/16-44/6250	Tristanite 5km	4.6×10^{-5}	4.0×10^{-2} (~145 day)	6.72×10^{-6} (2.36×10^{3} yr)	4.31×10^{3} (116 s)	(8.45×10^{-1}) 6.85 day
8/6-12/5290	Comenditic Trachyte 30km	1.4×10^{-6}	7.0×10^{-3} (13.7 yr)	1.16×10^{-6} (8.15×10^{4} yr)	3.61×10^{7} (2.3 hr)	(2.10) 16.50 day
8/25-54/6397	Comendite 30km	1.5×10^{-7}	2.5×10^{-3} (38.0 yr)	-----	1.12×10^{2} (7.4 yr)	-----
A.O.B. plus Lherzolite Nodules	Alkali Basalt 30km	3.97×10^{-1}	4.91 (7.1 days)	1.20×10^{-3} (79.2 yr)	2.59×10^{5} (12 sec)	(3.04) 11.43 day

- Velocities in cm/sec
- A depth of nodule incorporation is assumed for each sample to calculate rise times or velocity
- Re = Reynolds Number

expected from the arguments for magma emplacement in the crust governed by fracture propagation (Anderson and Grew, 1977). Using the model with its buoyancy drive mechanism, all types of magmas encountered at Level Mountain can rise from mantle depths in a matter of hours.

Rise times can also be estimated by calculating the time required to heat a nodule through its melting point. This is essentially a "Newton's Law of Cooling" calculation. Several assumptions and preliminary observations should be noted. In Clark (1966) it is shown that refractory minerals have higher thermal conductivities than melts of higher silica content. In keeping with this observation, an inclusion made up of refractory minerals will tend to have a very flat thermal profile as it heats up in a melt. Forced convection of the magma and turbulent flow will tend to transport heat to the nodule faster than assumed in these calculations, which will diminish the residence time to melting. For any positive density contrast (nodule greater than melt) some crossflow must exist so that this time estimate will be a maximum. Spherical nodules have the highest volume to surface area ratio so that any other geometry will enhance heat transfer and diminish time to melting. For this model the characteristic time is the duration of the heating process, only up until the nodule solidus is achieved. For real nodules once the solidus has been reached there will still be a finite time of melting associated with kinetic effects such as diffusion and

reactive melting. In this model, for steady state
conduction, the rate of change of temperature with time is
given by Tuma (1976) as

$$dT/dt = -hc\Delta TA/V\rho Cp$$

where hc = heat conduction coefficient, $cal/cm^2-sec-°C$

ΔT = initial temperature differential, °C melt -
nodule

A,V = surface area and volume of nodule, cm^2, cm^3
respectively

ρ = density of nodule

Cp = heat capacity of nodule

The heat capacity, density and geometry of the nodule
are assumed to be constant up until melting. To extend the
model through melting, the heat capacity would have to be
replaced by a term including the heat of melting and any
excess heats of mixing associated with diffusion processes.
For a spherical nodule geometry A/V = 3/r. Newton's Law of
Cooling states

$$\Delta T(t) = \Delta T_o e \exp(-\alpha t)$$

$$\text{where } \alpha = (dT/dt)/\Delta T_o.$$

The only remaining quantity to be evaluated is hc. Kreith
(1973) gives hc = kN/D where k is thermal conductivity and N
is Nusselt's number, which for Reynold's numbers Re ≤ 10.0 is
approximately equal to 2.0. Values of k for minerals and
some rocks are published in Clark (1966). A sample
calculation is presented for a general alkali basalt and a
lherzolite nodule assuming the basalt to be at a liquidus

temperature of 1225°C, the lherzolite initially at 1045°, with a solidus at 1245°C (CO_2, 9.1kbar, Yoder, 1976). Then:

hc = (0.011)2/15 = 0.00147 cal/cm²-sec-°C

dT/dt = (-0.00147)3(210)/7.5(3.3)5.9(10)
=6.48x10⁻⁴ °C/sec

α = 3.08x10⁻⁶, T(t) = 10° and T_0 = 210°.

Finally the heating expression can be rewritten in terms of t to give:

t = ln ($\Delta T(t)/\Delta T_0$)/-α

which with substitution of the appropriate values,

t = ln(10/210)/-3.08x10⁻⁶ gives

t = 9.87 x 10⁵ seconds or 11.43 days.

Assuming the lherzolite to have become incorporated at a depth of 30km yields a minimum ascent velocity of 3.039 cm/sec. Depending on the assumed depths of incorporation for the inclusions the model ascent velocities are generally between those estimated by Stoke's Settling and buoyant rise, see table 9-4.

Carmichael et al (1977) present an ascent model whereby spherical magmatic diapirs rise buoyantly, yet frictionally retarded, through a very viscous upper mantle. The relationship they derive is $R^2 = 3Vn/g\Delta\rho$, where R is the effective radius of the magma diapir, V is the ascent velocity and n is the viscosity of the upper mantle. The value of n, derived from isostasy, and typically used in geodynamic arguments is 10²¹ poise (Cathles, 1975). A few trial calculations, using reasonable density contrasts and

assuming a value for either V or R to solve for the other, reveals unreasonably large radii, of hundreds to thousands of km, or unreasonably slow velocities, which for depths of 30 to 100km imply rise times of tens of millions to billions of years. The Cordilleran lithosphere is thinner and the upper mantle is softer, with lateral variations in the effective viscosity spanning two orders of magnitude at the 100km depth range (Ranalli, 1980). The diapiric transport calculation can be rearranged to estimate a viscosity for the upper mantle that would be volcanologically more reasonable. Consider a peralkaline trachyte flow, PBE from Meszah Peak. The volume of the flow is $4.8 \times 10^{-3} km^3$ for an equivalent spherical radius of 105m. Assuming a slow ascent velocity of 1.16×10^{-6} cm/sec, and densities for mantle and melt of 3.3g/cc and 2.4g/cc respectively, results in a calculated estimate for n(mantle) of 2.78×10^{16} poise. For a hypothetical diapir volume of $1km^3$, a velocity of 10^{-6} cm/sec and the same density contrast, the value of is 1.13×10^{18} poise. This begins to look plausible for the situation of a partially molten upper mantle and transport of diapirs having about 10 flow volumes worth of magma. For the ascent velocity of about 10^{-6} cm/sec, it would require approximately 42,000 years to traverse 13km of upper mantle. The evidence from age dating attempts suggests that the major eruptive periods are separated in time by tens of thousands of years. This coincidence lends support to the buoyant diapir concept and calculations discussed.

Assuming that all of the Level Mountain lavas rose as a single magma diapir from a hypothetical depth of melting and segregation of 105km to 30km. The total volume of volcanics is 1500km^3 for an equivalent diapir radius of 7.1km. As the lavas are predominantly basic, a more reasonable density contrast is 0.6g/cm^3. For a normal upper mantle viscosity (10^{21}poise), the calculated ascent velocity is 9.89 x 10^{-8}cm/sec and the traverse time to the base of the crust is 7.58 x 10^{13}sec or 2.4MY. The age for the lowest flows sampled in the Little Tahltan Canyon is interpreted from paleomagnetic evidence to be about 6.4MY. The combination of these two ages, 8.8MY, should be close to the origin time for the Level Mountain magmas. In Hamilton, Baadsgaard, and Scarfe (1978) a whole rock Rb-Sr age of 9.4±1.0MY was reported and interpreted as possibly representing some precursor thermal event in the upper mantle. The coincidence of the reported and the modelled date may lend some support to the mantle diapir model.

Carmichael et al (1977) in using the same model, and reasonable model parameters for alkali basalts and tholeiites, derived an apparent viscosity for the upper mantle of 5.3x10^9 poise. They concluded that, while this is unlikely to represent the viscosity of the whole upper mantle, it could represent the viscosity of a thin lubricating sheath of partially fused mantle material surrounding the diapir. They also did a conductive heat loss calculation, inferring a drop of about 2°K for flow sized

bodies ascending at typical nodule settling velocities.

Carmichael et al (1977) also calculated convective heat loss for these magma diapirs with thin boundary layers. For diapirs in the volume range 0.03 to 0.185km³, the boundary layers were all less than 40cm thick, which is one per mil of the diapir radius. The temperature losses associated with laminar boundary layer convection were 21° and 7° respectively. The losses corresponding to a turbulent boundary layer were higher, 86° and 39° respectively. Using the appropriate physical parameters for the Level Mountain hawaiite flow, 8/25-50/6397, and a model transport from 100km, the laminar convective boundary layer model gives a temperature drop of 3° while the turbulent case was 23°C. Convective heat losses offset by proportional crystallization could be a significant driving force and mechanism for differentiation even at mantle depths. This might be a means to derive large volumes of hawaiite from a more primary composition while still in the mantle depth range.

In addition to conductive and convective heat losses some other types of heat changes need to be considered. The adiabatic gradient is given by Yoder (1976) to be between 0.2 and 0.5°C/km. This is equivalent to -20° to -50° for a 100km path. For isenthalpic decompression, Waldbaum (1971) cites a value of adiabatic heating on decompression which may be as great as 22°C per kilobar. Clearly this is a mechanism to offset convective heat losses and even perhaps

to provide superheat for an ascending magma body. This mechanism could provide sufficient heat for a magma to assimilate significant quantities of wall rock, whether in the upper mantle or crust. Here the ascent velocity would be the crucial parameter. Again it is pointed out that any rising magma must undergo decompression and, if this can generate heat and drive assimilation processes, it may be difficult indeed to transport and erupt a primary magma. Thermal changes due to viscous heating and transportive friction may also be significant but their effect is thought to be less than adiabatic and convective effects (Carmichael et al, 1977).

VOLUME ESTIMATES OF LEVEL MOUNTAIN VOLCANISM

Volume estimates have been made for thirty-five typical eruptive events from Level Mountain. Estimates have been made for single eruption flows, tuffs, domes, and dykes representing the entire range of compositional types. Although estimates cover the time span of volcanic activity, the younger events are more heavily represented due to preservation and mappability. Dyke and vent pipe thicknesses were estimated at the base of the plateau as this was the volume of material added to the volcanic pile during an eruptive event. Volume estimates are presented in Table 9-5 along with characterizing information for locality, map unit = age, and composition. The entire range of volumes is 6.12×10^8 m^3 (0.612km^3) to 1.02×10^6 m^3 (0.001km^3). Typical

Table 9-5. Volume Estimates of Some Level Mountain Eruptive and Hypabyssal Events

Map Unit	Magma Type	Feature	Locality	Volume M³	(km³)	
4	Alkali Basalt	Dyke	N.E. Plateau	5.28×10^6	0.528	
3	Alkali Basalt	Dyke	W Fork Beatty Ck.	9.25×10^7	0.093	
9	Ankaramite	Cockscomb Dyke or Lava Field 16/19	Wrathall Plateau (NE)	3.17×10^7	0.032	Dykes Avg (6) 0.121±0.82 km³
9	Ankaramite	Dyke	Wrathall Plateau	3.15×10^7	0.032	
9	Ankaramite	Vent Pipe Flow	Wrathall Plateau	9.59×10^6	0.010	
9	Ankaramite	Dykes & Flows	Wrathall Plateau (SW)	3.68×10^8	0.368	
1	Ankaramite	Flows	Little Tahltan Canyon	6.25×10^6	0.006	
9	Alkali Basalt	Tuya 01	Little Ketchum Lake (SW)	2.61×10^6	0.003	
4-9	Basalt	Tuya	Eastern Plateau	1.76×10^6	0.002	
6-9	Hawaiite	Scoria Vent 69/6178-6183	Hanging Valley S. of Meszah Peak	7.60×10^6	0.008	
3	Ankaramite	AA Flow	Western Plateau Margin	1.02×10^6	0.001	
2	Alkali Basalt	AA Flow 6/3240	Little Tahltan canyon	1.20×10^7	0.012	Flows Avg (13)
3	Palagonite Tuff Breccia	------ 75/8/PT	Western Plateau Margin	5.44×10^7	0.054	0.012±.004 km³
8-9	Alkali Basalt	Columnar Flow 24/2	South Dudidontu Ridge	7.62×10^6	0.008	
2	Basalt	Ponded Flow	Eastern Plateau	1.94×10^7	0.019	
8-9	Hawaiite	Columnar Flow 80/6375	North Ridge Kakuchuya Valley	3.88×10^6	0.004	
4	Hawaiite	Columnar Flow	Western Plateau Margin	1.50×10^7	-----	
3	Basalt	Columnar Flow PAP	Little Tahltan Canyon	1.60×10^6	-----	
9	Hawaiite	Scoria & Ponded PBT	Meszah Peak Summit	2.01×10^7	-----	
7a	Trachyte	Stock 8/25-52/5880	N. of Meszah Peak	6.12×10^6	-----	
7c	Tristanite	Dyke 8/16-44,LM111A	Central Chain	1.44×10^8	-----	Avg (8) cones, stocks, dykes .142±0.68 km³
6a	P. Trachyte	Flow PBE	Hanging Valley S. of Meszah Peak	4.80×10^6	-----	
7b	Comendite	Glassy Dykes 8/25-52/6890	Divide Beatty/ Kakuchuya	4.00×10^7	-----	
7b	Trachyte	Dome 60/6350	Divide Beatty/ Kakuchuya	8.08×10^6	-----	
6a	Pantellerite	Tuff 8/10-1/4925	Fork of Beatty Creek	1.91×10^8	-----	Avg (8) flows, tuffs, sills .008±.002 km³
6a	Pantellerite	Tuff 8/11-29	S. Valley Vall, N. Fork Beatty Cr	1.92×10^7	-----	
7a	Rhyolite	Tuff & Scoria 79/6700	Ridge ESE of Meszah Peak	5.33×10^6	-----	
7a	C. Trachyte	5 Tuff & Scoria Domes LM120 Bomb	Beatty/ Dudidontu Divide	9.42×10^7 each	-----	Basic Avg (19) Salic flows & tuffs 1.058±.78×10⁷
6a	C. Trachyte	Laccolith/Sill 92/5060	Kakuchuya Valley	4.80×10^8 / 1.17×10^7	-----	

historic basalt flow volumes from Hawaii and elsewhere are given as 0.03 and 0.185km³ (Carmichael et al, 1977). The average volume of five post-glacial basalt, basanite and nephelinite cinder cones from the Cariboo, Chilicotin and Stikine regions of B.C. is 0.0134 km³. A large Pleistocene basaltic tuff cone near Jacques Lake (Campbell, 1961) has a volume of 0.126km³. Compared to these, the Level Mountain events appear to be of ordinary size. The volume estimates have been subdivided into basic and salic types as well as into flows versus hypabyssal intrusions. It is apparent that at Level Mountain the dykes, stocks and domes are an order of magnitude larger in volume than the flows and ejecta. Flow volumes are taken to be single eruptive events, while dykes and stocks may be intermediate in size between eruptive events and eruptive episodes. There is no statistical difference in size for basic versus salic types in either the eruptive or hypabyssal group. This would seem to indicate that eruptive volumes are determined by common energetics of magma rise or by a common set of volcanic plumbing, rather than by the relative volumes of melting or differentiation events.

The volume of eruptive episodes, taken to be synonymous with the sequential map units, have been estimated using topographic maps at 1:50,000 scale for elevation control and a grid overlay for area. Volumes have been reconstructed to include materials eroded form the plateau margins and youthful alpine glacial valleys. Model densities have been

assigned to each unit on the basis of average physical and chemical properties for rock types present. Time spans for map units have been estimated from all available sources of field and laboratory data. The average time intervals between flows have been calculated for a typical flow volume of $0.01km^3$ in size. This data is summarized in Table 9-6.

There have been approximately 85,000 flow sized eruptions at Level Mountain over a time period of about 6 to 7MY. The lifespan of the volcano is clearly divided into 39% initial plateau building and a 61% later stratocone development. The average time span calculated for flows of the plateau building period is 43 years while for the statocone development phase the interval is 226 years. Field mapping and geomorphology indicate that the activity was likely to have been more intense with widespread contemporaneous eruptions separated by periods of hundreds of years of quiescence. The figure of 43 years for the plateau period seems reasonable as there was insufficient time between sequential flows for extensive soil development or vegetation to have occurred.

Of the total $857.6km^3$ of volcanics, 80.8% was basaltic while 19.2% was salic and dominantly peralkaline. The plateau building site was wholly basaltic. The stratocone stage, with a repeated bimodal process, was 85% salic in character.

In addition to the Level Mountain Volcanism, the volumes have been estimated for the other major centres in

Table 9-6. Volume and Mass Estimates for Level Mountain Volcanisms as a Function of Time

Map Unit or Magma Pulse	Time Span M.Y.B.P.	Duration	Dominant Composition	Volume (km³)	Model Density	Mass in Kg	Years/Flow
8-10	1.2 -0.0	(1.2)	basic	0.83	2.84	2.36×10^{12}	14,458
7a-c	2.4 -1.2	(1.2)	salic	55.85	2.61	146.0×10^{12}	215
6b	3.25-2.4	(1.05)	basic	14.17	2.86	40.5×10^{12}	188
6a			salic	41.68	2.56	107.5×10^{12}	
5b	4.2 -3.25	(.95)	basic	15.00	2.82	42.4×10^{12}	116
5a			salic	67.11	2.44	164.0×10^{12}	
4	4.6 -4.2	(.4)	basic	.165.79	2.71	$449. \times 10^{12}$	24
3	5.6 -4.6	(1.0)	basic	165.79	2.77	$459. \times 10^{12}$	60
2	6.3 -5.6	(0.7)	basic	207.19	2.78	$576. \times 10^{12}$	34
1	7.0 -6.3	(0.7)	basic	124.18	2.73	$339. \times 10^{12}$	56

Total 857.59 Avg 2.71 Total 2325.26×10^{12}

for an average flow volume of 0.01 km³
and an time span of 7×10^{15} yr.
this means an average of one flow per 82 years

the Stikine Volcanic Belt. This information is presented in Table 9-7 along with some estimates of dimensions pertaining to the source region. The total 1710km³ of volcanics outcrops over an area of 8629km² in the Stikine Volcanic Belt which has a total area of 70,000km³. The volumes and areas of the eleven major volcanic centres of the Stikine show a logarithmic distribution. Level Mountain and Mount Edziza are the largest in both area and volume. Using the total volume estimated and a time span of 5MY, it is apparent that the Stikine Volcanism is small in comparison to the Columbia River Plateau or the East African Rift and that the extrusion rates are lower by two orders of magnitude.

The volume data on the Stikine volcanism can be used to evaluate two possible source models. The two models are (i) partial melting of a slab of upper mantle and (ii) upper mantle diapirs below each of the eleven major centres. The slab hypothesis (using the surface outcrop area as an estimate of source region extent) implies the removal of a layer up to 180m thick beneath the volcanic centres. If the volume is derived over the extent of the Stikine Volcanic Belt, the removed layer may be as thin as 23m. When these slab calculations are performed for each centre, the calculated layer thickness varies from 76m to 532m with a mean of 235m and a standard deviation that is 33% of the range. Assuming that 5% to 25% partial melting accounts for the volcanics, and that this volume may be efficiently

Table 9-7. Total erupted volumes for the Major Centers of the Stikine Volcanic Belt

Center	Lat.N/Long.W	Vol (km³)	Surface Area (km²)	Source Region Estimates Slab Thickness (m)	Spherical drapir radius (km)
Kawdy Plateau	58°52'/131°10'	35	997	35	2.029
Heart Peaks	58°38'/132°00'	100	499	200	2.879
Level Mountain	58°25'/131°15'	860	3324	259	5.899
Tahltan Plateau	58°05'/131°35'	50	184	272	2.285
Stikine River	58°00'/131°00'	5	66	76	1.061
Mt. Edziza	57°30'/130°40'	500	1773	282	4.924
Tanzilla Plateau	58°30'/129°35'	35	166	211	2.029
Castle Rock	57°52'/130°15'	10	50	200	1.337
Klastline Plateau	57°25'/129°50'	50	1440	35	2.285
Hoodoo Mtn.	56°44'/131°20'	40	83	482	2.122
Iskut River/Mt. Dunn.	56°38'/130°45'	25	47	532	1.814
	Total	1710	Total 8629	Mean 235 s.d. 162	Mean 2.606 s.d. 1.484

removed, implies a thickness for the melting region of between 0.94km and 4.70km for the mean figure quoted, or 0.092 to 0.460km for the minimum case of partial melting below the entire belt. When the eleven estimates are considered as a population, the distribution is normal and 85% of the entire Stikine Volcanism is accounted for within a thickness variation of ±0.5 standard deviation of the mean. All of the thickness estimates lie within ±2 standard deviations of the mean. From these model data it appears geologically reasonable that the Stikine Volcanism could originate from a thin zone of partial melting.

For the thermal model presented in this chapter, the partial melting zone could be as thick as 6km. Using this as a maximum estimate, and keeping the same levels of partial melting, an estimate of melt extraction efficiency can be made. A relatively inefficient melt extraction process has been inferred from studies of lherzolite textures (Waff and Holdren, 1980). For the case that melt generation is localized, the efficiency of melt extraction is between 78.3% and 15.7%, while for the case of a general partial melting zone beneath the entire Stikine, the melt extraction efficiency is between 7.7% and 1.5%. In either case a period of partial melting results in a considerable amount of material that may be left behind. For basaltic partial melts, the melt that stays behind could generate regions of gabbro in a more ordinary peridotite upper mantle. The idea of inefficient melt extraction is important to the concept

of upper mantle differentiation but has been proposed on other terms (Mysen and Boettcher, 1975; Lloyd and Bailey, 1975; Boettcher and O'Neill, 1980). Sufficient preconditioning of the upper mantle to generate gabbroic pods (plagioclase plus pyroxene) could result in the derivation of more salic magmas in subsequent partial melting events. It is noteworthy that the three largest centres of the Stikine have both the long spans of activity and the salic lavas one would expect from such a two stage process.

The second source model for the Stikine postulates separate diapirs below each of the centres which, successively tapped, could account for the cumulative individual volumes. For a spherical diapir model, the radii so calculated for the 11 Stikine centres are normally distributed. The mean radius is 2.61km and the range is 1.06km to 5.90km with a standard deviation that is 31% of the range. Unlike the slab calculation, only 12% by volume of the Stikine Volcanism is accounted for by average sized diapirs. Another way of stating this conclusion is that, if diapirism explains the Stikine volcanism, the diapir size is highly variable. This implies that 88% of the volcanism must be accounted for by two mega diapirs of extraordinary size. Therefore the first source mode (slab partial melting) in localized or widespread regions seems to be the more reasonable hypothesis.

THE ENERGETICS OF MELTING AND RISE

The Energetics of Volcanism at Level Mountain and for the Stikine

Volcanism can be considered as an energy dissipation process. The thermal requirements to initiate and maintain this process include mantle preheating, phase change energy associated with melting, and the work performed in magma transport to the surface. The total energy released at the surface can be considered as a contribution to the total heat flow.

As a monitor of the Level Mountain volcanism, the total energy dissipated will be considered as a function of time. The timing comes from magnetostratigraphy and limited age dating control. Mass estimates for successive units were derived from field mapping and laboratory density measurements. Three energy terms are considered. The cooling of lavas from their liquidus temperatures to surface conditions is expressed as a heat capacity intergral, using heat capacities for typical flows from each unit as calculated in ROCK. Due to the small variation (± 50°) in liquidus temperatures, regardless of lava composition, the value of 1200°C was used for all calculations. The heat of fusion values apply to liquidus temperatures for specific compositions considered representative of each unit. The transport work is expressed as a potential energy term (mgh) for the total mass of each map unit and the constant depth

of 35km. These data and calculations are summarized in Table
9-8. The largest energy contribution for each unit is the
cooling term which is about five times the heat of fusion.
Map units 5a, 6a, and 7a-c are dominated by salic lavas. The
energy components of salic lavas are distinctive. Due to the
low heats of fusion for salic lavas, the lift energy
required for magma transport exceeds the phase change
energy. For the remaining units, dominated by basaltic
compositions, the reverse is true.

A graphical representation of the cumulative energy
dissipated by Level Mountain volcanism is presented in
Figure 9-2. The energy ploted is the sum of three terms
discussed above. The graph should be read as: 0.979×10^{21}J
was dissipated between the onset of volcanism and 6.3 MY
before present, etc. Two and possibly three distinct stages
are present. The shield building basaltic volcanism (units 1
to 4) has the highest rate of energy dissipation, such that
79% of the total energy expended had occurred by 4.2MY
before present. The overall rate (which appears to be
constant) was 1.87×10^{21}J/M.Y. For the plateau surface area
of 3324 km^2, this rate is equivalent to 17.8 mW/m^2. The
closest heat flow measurements in northern British Columbia
are Dease and Hotailuh which average 73.5 mW/m^2 (Jessop,
Souther et al, 1980 in prep.). Presuming the heat flow to be
similar at Level Mountain during plateau building times,
then volcanism represents 24% of the total heat flow. The
next stage, roughly equal in duration, corresponds to the

Table 9-8. Energy Dissipated by Level Mountain Volcanism

Map Unit or Magma Pulse	Mass (1012 Kg)	CP (J/Kg K)	1500 SepdT cooling (1018 J)	H (1018 J)	Mgh (1018 J)	E by pulse (1018 J)
8-10	2.36	1390	4.92	0.89	0.81	6.62
7a-c	146.0	1360	299.	39.7	50.1	388.80
6b	40.5	1411	85.7	15.3	13.9	114.90
6a	107.0	1381	222.	29.1	36.7	287.80
5b	42.4	1424	90.6	16.0	14.6	121.20
5a	164.0	1345	332.	44.8	56.3	433.10
4	449.0	1405	947.	169.	154.	1270.0
3	459.0	1450	999.	173	158.	1330.0
2	576.0	1433	1240.	217	198.	1655.0
1	339.0	1446	735.	128	116.	979.0

6586.42X10^{18} J

Figure 9-2.
Cumulative energy dissipated by Level Mountain volcanism.
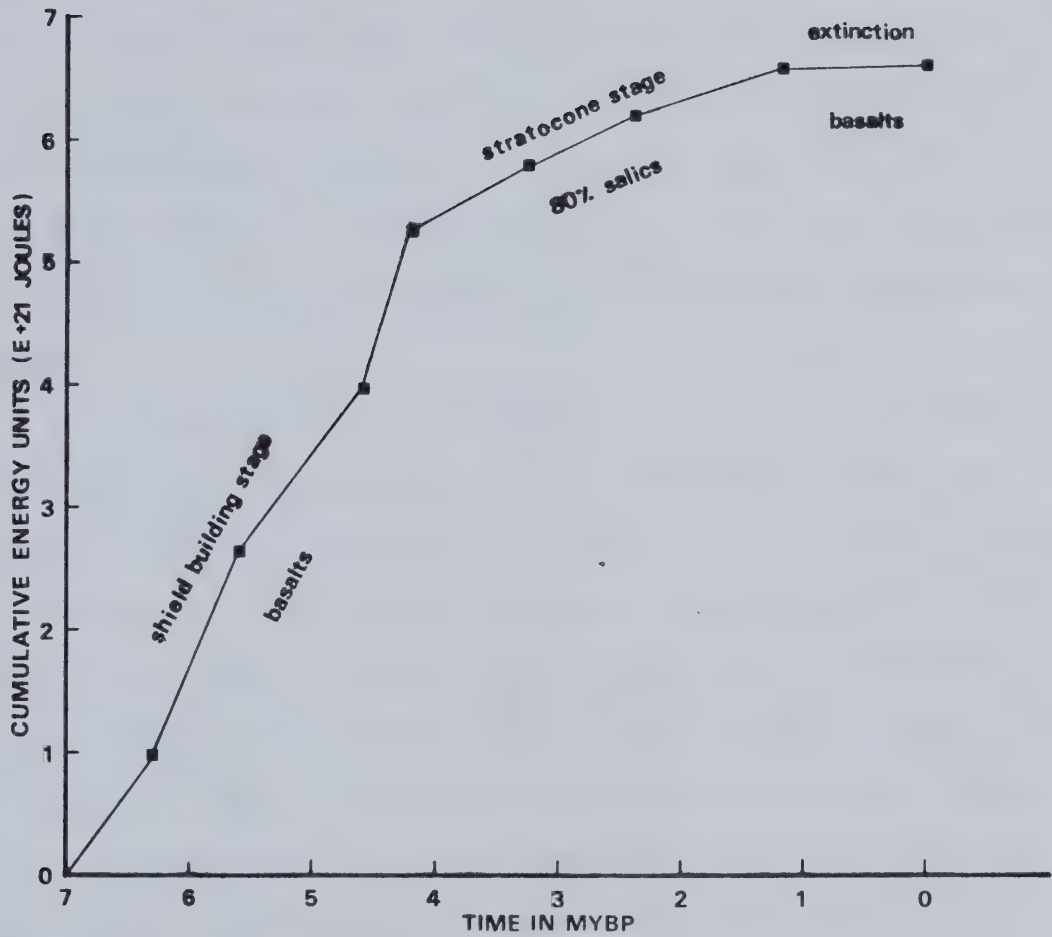
bimodal volcanism and stratocone building. Eighty two
percent of the energy dissipated in this stage is by salic
lavas. The rate here (also constant), is 0.45×10^{21} J/MY,
which is only 25% of the previous stage. However the surface
area of the stratocone cap is only 20% of the plateau as a
whole; expressed in heat flow units the rate for the
stratocone stage is 7.15 mW/m^2. This is still less than half
of the shield rate, and only 9.7% of the modern heat flow
values.

The final 1.2MY, with its low volume hawaiites and
alkali basalts, represents another reduction in the rate and
possibly signifies the extinction of Level Mountain. However
if the rate of the statocone stage is extrapolated to the
present, the time period is about right for the release of
another fifty cubic kilometers of lava. Mountain and for the
Stikine as a whole. While the preceeding discussion dealt
with the development of Level Mountain volcanism and the
total energy dissipated by the process, the following
section considers the minimum thermal requirements to
initiate and maintain the volcanism. Basic data for these
calculations and the results are presented in Table 9-9.
Assuming the mantle source region to be at the solidus
temperature, two additional energy requirements must be met:
(i) the heat of fusion for the melts and (ii) the potential
energy change associated with the magma transport. The
energy dissipated through normal heat flow is calculated for
Level Mountian and the total volcanic area within the

Table 9-9. Energy Requirements of Volcanism

	Level Mountain	Stikine Total
LAVA Volume (Km^3)	860	1710
LAVA Mass (10^{12}Kg)	2325	4634
Surface Area (Km^2)	3324	8629
TIME SPAN (my)	7.0	7.0
Heat of Fusion (cal/g)	85.5	86.6
SOURCE Volume * Km^3	15,623	40,556
SOURCE MASS 10^{12}Kg	57,556	133,835
Cp J/kg·K for 1050°C 4 phase spinel peridotite	1300	1300
Modern heat flow mw/m^2		73.5
Total heat flux for 7my (J)	5.4 ×10^{22}.	1.4 ×10^{23}
a) H (J)	8.32×10^{20}	1.68×10^{21}
2) Mgh (J)	7.98×10^{20}	1.59×10^{21}
I. BASE CASE HEAT (J) 1+2	1.63×10^{21}	3.27×10^{21}
equivalent heat flow mw/m^2 T from 12% of H.F. (°K) available for source heating	2.2 (3% of HF) 96	1.7 (2.3% of HF) 97
II. Total heat budget for 96° heating (J) equivalent heat flow mw/m°	860 8.11×10^{21} 11.0(15% of HF)	1710 2.0×10^{22} 10.5(14% of HF)

* Source volume has same surface area and 4.7 km thickness

Mass conversion assumes mantle source density of 3.3 g/cc

Stikine for the last 7MY. For the Stikine this value is 1.4x10^{23}J. For Level Mountain this works out to 3% while for the total Stikine Volcanic region it is 2.3% of present heat flow for northern British Columbia.

Additional energy would be required for pre-heating of the mantle source region. For this calculation model source region dimensions are estimated from the surface outcrop of volcanism and a slab thickness of 4.7km. Source region density was assumed to be 3.3g/cc. The heat capacity for a four phase spinel periodite was calculated from data in Robie, Hemingway and Fisher (1978) to be 1300 J/kg-°K in the temperature range of interest. The heat capacity integral was solved for a temperature interval by assuming an amount of heat potentially available. Less than 40% of a surface heat flow value of 73.5 mW/m^2 probably arises from a steady state mantle contribution. A value of 12% of the total heat flow is equivalent to 30% of the mantle heat flux. This implys that less than 100° of heating can be performed over a 7MY period. Obviously heating of this type requires geologically long periods of time, or high heat fluxes, or small source regions in some combination. For the 12% pre-heat budget cited above, the pre-heat requirement is 80% and 84% of the total energy requirements for Level Mountain and the Stikine respectively. If the energy requirement for volcanism is expressed in heat flow units, these heating models represent about 15% of the modern heat flow discussed above.

The low volume alkali magmatism for the Late Cenozoic and the Stikine could be initiated and maintained by a thermal contribution equivalent to a small percentage change in the normal heat flow. If the source region must be heated to the peridotite solidus through an interval of a few hundred degrees, in the space of a few million years, an increase equivalent to 25% of the normal heat flow may be required. On the other hand, an increase in available heat as low as 2.5% could initiate and maintain alkaline volcanism from a source region already at the periodite solidus.

As a final note, the total energy dissipated through volcanism in the Stikine can be compared to a change in tectonic strain or potential energy. This can be likened to a release of mantle strain energy through subsidence of the crust over the entire Stikine Volcanic Belt. The area of the entire Stikine Volcanic Belt is estimated to be $7.19 \times 10^{10} m^2$. For 25km of crust of mean density $2800 kg/m^3$ the total mass of crust under the Stikine is $5.03 \times 10^{18} kg$. Using the expression $E = mgh$ to equate the dissipated heat and potential energy (where: $E = 1.11 \times 10^{22} J$ $m = 5.03 \times 10^{18} kg$ and $g = 9.81 m/s^2$) h can be calculated to be 225m. The efficient release of about 0.2km of strain build up over an area the size of the Stikine Volcanic Belt is equivalent to the energy released as volcanism. Whether such tectonic strain preceeded the Late Cenozoic volcanism or actually was responsible is unknown. The release of a geologically small

amount of tectonic strain through a melting process could be responsible for this type of low volume alkaline volcanism without recourse to unusual compositions or events in the upper mantle, or large scale lateral geological movements such as treated in plate tectonics theory. A model of strain release through volcanism is particularly appealing for the Intermontane Belt as the strain release through seismicity is anomalously low (Milne et al, 1970).

MODELLING OF A HEAT FLOW AND A GEOTHERMAL GRADIENT FOR LEVEL MOUNTAIN AND THE STIKINE

The intent of this section is threefold, first to review existing Cordilleran heat flow data, second to calculate a steady state conduction model and third to construct a preferred PT model for the geothermal gradient under the Stikine and relate it to the origin of the Level Mountain volcanics. The steady state conduction model is in general, representative of continental geotherms. These continental geotherms are characterized by surface heat flow in equilibrium with heat flowing into the base of the lithosphere, plus a term for internally generated heat from radioactive decay (Pollack and Chapman, 1977).

A review of existing Cordilleran and Canadian heat flow measurements is presented in Table 9-10. It is noteworthy that the value of 73.5 mW/m², used for the Stikine in the preceeding section, is virtually identical to the Western Canadian average. The Cordilleran values are somewhat higher

Table 9-10. A summary of Cordilleran and Other Canadian
Heat Flow Data

Cordillera	mW/m²	Corrected[1]	Gradient °C/km
Buckley lake	67	74	
Dease	91	100	
Hotailuh	56	62	
Penticton*	67	79	34.7

Canadian, average heat flow by region, uncorrected

Maritimes	(3)	38.5	Eastern Canada
Quebec	(4)	32.2	
Ontario	(12)	41.0	36 ± 2
Manitoba	(1)	33.5	
Alberta	(2)	64.1	Western Canada
N.W.T.	(1)	83.7	73 ± 6
Cordillera	(4)	70.3	

data from (Jessop, Souther et al 1980 in prep.)
(Jessop and Judge, 1971)
(Lee and Clark, 1966)

1. Corrected for the effect of Pleistocene glaciation after
the measurement of Jessop (1971).

than the continental average of 42 mW/m², but not so high as many of the circum-Pacific regions which may have values as high as 170 mW/m². Northern B.C. lies on the northern extension of the Western North American thermal high, with a regional heat flow of about 70mW/m² (Pollack and Chapman, 1977). For the Cordilleran thermal anomaly zone, there is a sharp eastward gradient of decreasing heat flow (Roy et al, 1968). Within the thermal anomaly both the crust and mantle are hotter than to the east. The corrected shallow geothermal gradient deduced for Penticton (Jessop and Judge, 1971) is also high for a continental geotherm.

A model for heat flow at Level Mountain has been constructed assuming a simple three layer geometry. The model, in general form, is steady state conductive heat transfer through a series of arbitrarily wide parallel plates of known thickness and conductivity. The solution to Laplace's equation is given by:

Q/At = ΔT/SUM(l(i)/k(i)).

The lefthand side of the equation is heat flux per unit area per unit time, and the right hand side is the net temperature difference across all the layers, divided by the sum of the individual layer thickness-thermal conductivity quotients. Q/At is replaced by a heat flow value and the k corresponds to geologically reasonable choices for layer compositions. With these values set, the thicknesses and temperatures are no longer independent variables so that a geothermal gradient can be calculated within acceptable

petrological and geophysical constraints.

The preferred model for steady state heat flow is 81.7 mW/m² with a two layer crust and one layer upper mantle characterized by:

	l (km)	k (W/m°K)
crust 1	1.50	3.14
crust 2	23.95	2.2
upper mantle	-----	3.22

The major limitation of this model is probably the steady state assumption. The model and selected solidus/liquidus data are presented in figure 9-3. Higher heat flow values would cause unrealistically high geothermal gradients that do not agree with geophysical or petrogenetic constraints. Lower heat flow values (10%) would depress the melting zone to depths below 48km which is considered unlikely. Variations at this level correspond to lateral temperature gradients of less than 0.6°C/km, which could explain the narrowness of the volcanic areas in the Intermontane Belt. Such small differences be supported by the natural variation in thermal conductivity with temperature for peridotites, by changes in proportion and composition of phases, or by very small amounts of tectonic stress (<1.0km). Caner's (1969) estimate for the Curie isotherm depth appears to be too great and his 750°C Moho isotherm appears to be too cool. The implication of this model is that the Moho under Level Mountain is about 25.4km, which would make it one of the shallowest values for the Cordillera. This model is

Figure 9-3.
Geothermal gradient for the Stikine for model calculations
and assumptions as discussed in text.
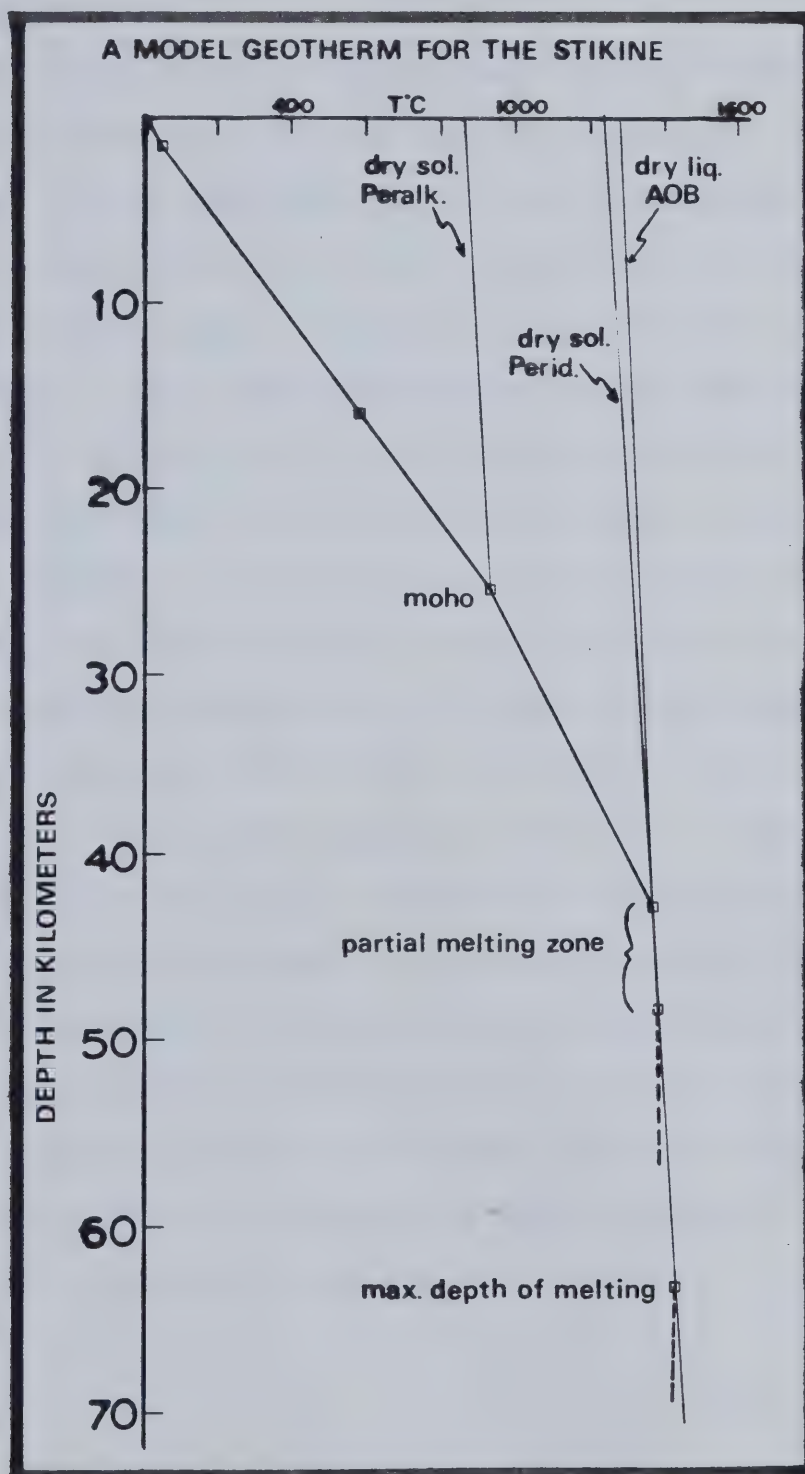
generally consistent with a mantle derivation for the Level Mountain lavas formed by the anhydrous partial fusion of spinel peridotite.

A characteristic of these steady state conduction models is a steeper geothermal gradient over most of the crust than in the upper mantle. For any reasonable choice of thermal conductivities, this geothermal gradient behavior holds for a wide range of hypothetical heat flow values (73 to 112 mW/m^2), Curie isotherm depths (16 to 18km) and crustal thicknesses (25 to 30km). The very shallow geothermal gradient is predicted to be lower in the volcanic pile as compared to adjacent areas with basement outcrop, or immediately beneath the pile in the crust. This is due to the high thermal conductivity for lavas. The Intermontane Belt in Southern and Central B.C. generally lacks a high velocity lid and the LVZ begins at the base of the crust. To more accurately fit such a constraint, the gradient in the upper mantle would probably be even more gradual. For a metasomatized alkali- and silica-rich upper mantle the thermal conductivity would be closer to lower crustal values and thus support a higher geothermal gradient. Varying the model in this direction would also lend support to a mantle derivation of peralkaline melts.

Chapter 10. GEOTHERMOMETRY AND GEOBAROMETRY ESTIMATES

INTRODUCTION

Spinel lherzolites are a common inclusion type for nodule-bearing alkaline lavas of the Intermontane Belt. Studies of phase chemistry and trace element concentrations have been reported by Littlejohn and Greenwood (1974), Fiesinger and Nicholls (1977), Fujii and Scarfe (1981) and Fujii et al (1981). Microprobe analyses of coexisting minerals from two spinel lherzolites nodules, one from Telegraph Creek and one from Grizzly Hill in Central B.C. are presented here. The various geothermometers relevant to spinel lherzolites are reviewed here. Equilibration temperatures have been estimated for the two Stikine localities: Telegraph Creek and Castle Rock (Littlejohn and Greenwood, 1974), the Selkirk material (Sinclair et al, 1977) and Grizzly Hill. The purpose of this is to estimate P,T conditions in the upper mantle beneath the Cordillera to determine the conditions of alkali basalt genesis for the Late Cenozoic, particularly at Level Mountain.

At equilibrium, the partitioning of Al, Mg, Fe etc. between the four phases olivine, orthopyroxene,, clinopyroxene and spinel, is a function of bulk composition, temperature and pressure. Considerable attention has has been given to pyroxenes as geothermometers (Boyd, 1973; Wilshire and Jackson, 1975; Presnall, 1975; Stroh, 1976). Thermodynamic models may be constructed using tabulated

information from mineral thermodynamic studies (Robie et al,
1978) and experimental data from simplified analogs of the
natural peridotite system, $MgO-Al_2O_3-SiO_2$, (MacGregor 1974;
Fujii and Takahashi, 1978) and the enstatite-diopside join
(Mori and Green, 1977, 1976; Davis and Boyd, 1966; Lindsley
and Dixon, 1975).

Consider the partition of magnesium between coexisting
orthopyroxene and clinopyroxene

$$Mg_2Si_2O_6 \quad = \quad Mg_2Si_2O_6$$
$$\text{opx} \qquad\qquad \text{cpx}$$

At equilibrium, (P,T, composition fixed),

$$U^{\text{opx}}_{Mg_2Si_2O_6} = U^{\text{cpx}}_{Mg_2Si_2O_6}$$

the chemical potential of enstatite into both pyroxenes is
equal (the sum of the $U(i)$ for the reaction is zero). Taking
the standard state for each component to be equal to the
pure phase, at some arbitrary temperature, the reaction can
be rewritten as:

$$U^{\circ}_{En} + RT \ln a^{\text{opx}}_{En} = U^{\circ}_{En} + RT \ln a^{\text{cpx}}_{En}$$

and the free energy for the reaction is then given by:

$$(\Delta G^{\circ})_T = -RT \ln \left[a^{\text{cpx}}_{En} / a^{\text{opx}}_{En} \right]$$

dividing through by RT and recalling the Second Law of
Thermodynamics:

$$\Delta G^{\circ} = \Delta H^{\circ} - T\Delta S^{\circ}$$

the preceeding expression can be rewritten as

$$\frac{\Delta G^\circ}{RT} = - \ln \left(a_{En}^{cpx} / a_{En}^{opx} \right) = \frac{\Delta H^\circ}{RT} - \frac{\Delta S^\circ}{R}$$

to give the basic form of the solid assemblage geothermometry expressions. Knowledge of ΔH° and ΔS° for the particular reaction in question may come from tabulated sources for minerals (such as Robie et al, 1978). Alternatively, ΔH° and ΔS° may be estimated from P-T slopes of reaction boundaries in experimental phase equilibrium studies using the Clapeyron relation.

The general form of the solid phase assemblage geothermometers is:

$$\ln K = \frac{\Delta H^\circ}{RT} - \frac{\Delta S^\circ}{R}$$

where K is the equilibrium constant (expression of activity products) for the reaction, and ΔH° and ΔS° are the enthalpy change (heat of reaction) and entropy change (order at a given T and P). As long as the ΔH° and ΔS° are accurately known and the simple mixing approximation applies, the geothermometers should be concisely expressed as simple log-linear expressions $\ln K = A/T + B$, where A and B are constants. This is the form generally given in geothermometry papers (Wells, 1977; Mori, 1977; Herzberg and Chapman, 1976) but it is important to keep in mind that A and B are not just arbitrarily selected numbers chosen to best fit a particular collection of data, but that they have

fundamental thermodynamic significance to them. Where the ideal mixing assumptions break down, or data on simple experimental fail to fit the more complex natural assemblages, empirical formulations have been made using polynominal expressions and adding additional terms, such as Mori (1977) or Wells (1977). It should be remembered that these extra terms are really without physical meaning and have only been added to force a mathematical fit to a collection of data. The need for such modifying terms only underlines the inaccuracies in our knowledge of $\Delta H°$, $\Delta S°$ and in the assumed solution models. Herzberg and Chapman (1976) point out their fits imply $\Delta S >8$ cal/mol° which does not seem high in this temperature range. Mori's values (1977) imply even higher ΔS (> 9.4 cal/mol°). This probably demonstrates the oversimplification of the mixing model, rather than inaccuracy in the thermodynamic or experimental data. The familiar thermodynamic form of the geothermometer can be rewritten as an equivalent polynomial in ln K so that all geothermometers can be expressed in a common form:

$$10^4/T°K = a(\ln k)^2 + b(\ln k) + c$$

where $c = 10^4 \Delta S°/\Delta H°$
      $b = 10^4 R/\Delta H°$
and   a is an additional term with no thermodynamic meaning.

The state of the art in geothermometry of spinel lherzolites is summarized in Table 10-1. In addition to the magnesium partition between pyroxenes used in the derivation above, (reaction 1, Table 10-1) the two most accurate

Table 10-1. GEOTHERMOMETRY OF SPINEL LHERZOLITES

ASSEMBLAGE:　　Forsteritic Olivine - ol
　　　　　　　　　Cr-Al Diopside - cpx
Magnesian　　　　Orthopyroxene - opx
(Mg,Fe,Al,Cr) Spinel phase - sp

REACTIONS: AT EQUILIBRIUM TO DEFINE P,T

1) $Mg_2Si_2O_6$ = $Mg_2Si_2O_6$, $(k1)_{P,T} = (a_{En}^{cpx}/a_{En}^{opx})$
　　opx　　　　　　cpx

2) $CaMgSi_2O_6 + MgAl_2O_4$ = $CaAl_2SiO_6 + Mg_2SiO_4$,
　　cpx　　　　　　Sp　　　　　　　　cpx　　　　　ol

$$(k2)_{P,T} = \left[a_{CaTs}^{cpx} a_{Fo}^{ol} / a_{Di}^{cpx} a_{Sp}^{sp} \right]$$

3) $Mg_2Si_2O_6 + MgAl_2O_4$ = $MgAl_2SiO_6 + Mg_2SiO_4$,

$$(k3)_{P,T} = \left[a_{MaTs}^{opx} a_{Fo}^{ol} / a_{En}^{opx} a_{Sp}^{sp} \right]$$
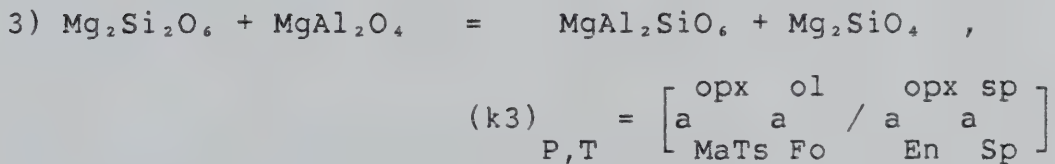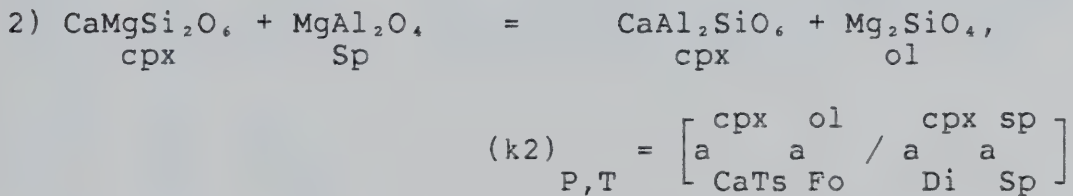
Table 10-1. (continued)

ACTIVITY DEFINITIONS[1]

(Pyroxenes): $M1(Al^{3+},Cr^{3+},V^{3+},Ti^{4+},Fe^{3+},Fe^{2+},Mg^{2+},Ni^{2+})$,
$M2(Mn^{2+},Ca^{2+},Na^{+},Ba^{2+},Fe^{2+},Mg^{2+})$

$$a_{En}^{cpx} = X_{Mg}^{M2} \cdot X_{Mg}^{M1}$$

In all cases Al^{3+} is partitioned between the tetrahedral site and M1 octahedral site on the basis of silica content in the pyroxene

$$a_{Di}^{cpx} = X_{Ca}^{M2} \cdot X_{Mg}^{M1}$$

analysis assuming the tetrahedral site is completely filled by Si^{4+} and Al^{3+}. After assigning the site specific cations Mg^{2+},

$$a_{CaTs}^{cpx} = X_{Ca}^{M2} \cdot X_{Al}^{M1}$$

Fe^{2+} are partitioned according to their proportions between M1 and M2, assuming ideal mixing.

$$a_{En}^{opx} = X_{Mg}^{M2} \cdot X_{Mg}^{M1}$$

$$a_{Mats}^{opx} = X_{Mg}^{M2} \cdot X_{Al}^{M1}$$

(Olivine)

$$a_{Fo}^{ol} = (X_{Fo}^{ol})^2 \quad \text{ideal solution} \quad (M)_2SiO_4$$

(Spinel)

$$a_{MgAl_2O_4}^{sp} = X_{Mg}^{A} (X_{Al}^{B})^2 \quad \text{for formula } AB_2O_4 \quad \text{normal spinel}$$

Table 10-1. (continued)

Calibrated Geothermometers:

Linear or polynomial regression fits of the form:

$$\frac{10^4}{T^\circ K} = a(\ln k)^2 + b(\ln k) + c$$

P = 12 Kbar

	a	b	c
*k_1	0	-1.192	4.337
*k_2	0	-1.171	4.754

after Herzberg and Chapman (1976)

P = 16 Kbar

	a	b	c
+k_1	0.41	0.37	5.7
*k_1	0	-1.177	4.215
+k_2	0	-1.08	5.12
*k_2	0	-1.083	4.799
†k_3	0.357	0.177	5.04
#k_3	0	-2.06	2.69

1 = Activity definitions conform to Nicholls and Carmichael
    (1972), Bacon and Carmichael (1973) and reference cited
    below
* = Herzberg and Chapman (1976), data from experimental and
    natural spinel peridotites
+ = Mori (1977), experimental data base
† = Mori (1977), after MacGregor (1974)
# = Mori (1977), after Obata (1976)

geothermometers are based on magnesium and aluminum partitioning between coexisting clinopyroxene spinel and olivine (reaction 2, Table 10-1) or aluminum and magnesium partitioning between coexisting orthopyroxene, spinel and olivine (reaction 3, Table 10-1). Reactions 2 and 3, involving the solubilities of alumina in pyroxenes, are not yet tested for Fe- and Cr-bearing systems. Application of theses geothermometers to the Cr bearing system may give too high a temperature estimate (Fujii and Takahashi, 1978). The definitions of activities are consistent with the geothermometry papers previously cited. Activity expressions are calculated for ideal structural formulae and using concepts of equivalent sites. For example the expression

$$a_{Fo}^{ol} = X_{Mg}^{M1} X_{Mg}^{M2} = (X_{Mg}^{M})^2 \quad \text{for } M1 = M2$$

shows the activity of the forsterite component in olivine assuming a random mixing for iron and magnesium between two octahedral sites. There is ambiguity in calculating structural formulae, particularly for pyroxenes, and several methods have been proposed (Cawthorn and Collerston, 1974; Fleet, 1974a,b). They have shown for pyroxenes of intermediate iron content, that random partitioning of Fe^{2+} between the two octahedral sites is not a very accurate assumption, because Fe^{2+} partitions in favour of Mg^{2+} into the M2 site. Magnesium and aluminum rarely exist in spinel analyses in stoichiometric proportions unbalanced by other cations. Problems arise in trying to fit data from different

laboratory studies. Additional difficulties may be encountered when fitting natural spinel lherzolites which have many additional components such as Ni, Mg, Na, Cr, Ti, V, Ba.

REVIEW OF PREVIOUS DATA FOR THE INTERMONTANE BELT

Fiesinger (1975) and Fiesinger and Nicholls (1977) performed geothermometry calculations both on solid assemblages and silica activities with coexisting lavas for spinel lherzolite and gabbroic xenoliths from Late Cenozoic lavas of the Wells Grey - Quesnel Highlands area B.C. Calculated equilibration temperatures ranged from 1050° to 1650°C with a total range of equilibration pressures from 13 to 50 kbar. The larger values for P and T here lie outside the spinel lherzolite stability field even though no garnet lherzolites are reported. There is too much variation in calculated P and T to be explained by any fractionation processes at either high or low pressure or to be explained by the inaccuracy in the assumptions and calculations of the geothermometers. The implication is that the nodules have been sampled from different depths and that the geotherm varies both in time and space for the Intermontane Belt. Similar conclusions have been obtained by Fujii et al (1981) using data for two localities from central and southern B.C. Takomkane (Boss Mountain) and Clark Creek (West Kettle River). Littlejohn and Greenwood's (1974) data for Jacques Lake (Quesnel Highlands) and Castle Rock (Klastline Plateau,

Stikine Volcanic Belt) indicate high and variable
equilibration temperatures according to the olivine-spinel
geothermometer of Jackson (1969). These estimates should be
considered with some doubt however, due to possible
subsolidus reequilibration of olivine and spinel and the
assumption of ideal solution in the spinels. Sinclair et al
(1977) also calculated high equilibration temperatures for
nodules from the Selkirk cone.

Chemical analyses of four phases were made by electron
microprobe on polished block mounts of nodules from Grizzly
Hill and Telegraph Creek. Data and structural formulae are
reported in table 10-2. All of these analyses gave high
totals between 101 and 106% due to problems with an oil film
on the beryllium window on the microprobe at the time the
data were collected. Despite the high totals, the recast
analyses compare favorably with other mantle inclusions
reported from the literature including samples from the
Cordillera (Littlejohn and Greenwood, 1974).

Activities have been calculated, from the structural
formula and site occupancy restrictions as summarized in
Table 10-1, for these nodules and for the four Castle Rock
samples from Littlejohn and Greenwood (1974), and the two
samples from the Selkirk Cone (Sinclair et al, 1978).
Temperatures have been calculated for the geothermometers of
Herzberg and Chapman (1976), Mori (1977) and Wells (1977)
for all four localities, see table 10-3. The Castle Rock and
Selkirk temperatures are derived from averages based on all

Table 10-2. CHEMICAL ANALYSES OF FOUR PHASES FROM INCLUSIONS

A. OLIVINES

	TCL 1004-41	GHL	
SiO_2	40.58	40.48	TCL 1004-41 also contained interstitial plagioclase <1% of An(55)Ab(43)Or(2) and mono sulfide solid solution phase approximately Py(64)Pn(36) having detectable Ni,Co,Zn and micro-inclusions of sphere
FeO	10.95	11.25	
MnO	.09	.13	
NiO	.40	.47	
MgO	47.90	47.67	GHL additionally contained <1% of interstitial alkali feldspar of An(0.7)Ab(41.0)Or(58.3) and a similar mono-sulfide solid solution to TCL
CaO	.09	0.0	
	------	------	
	100.01	100.00	

STRUCTURAL FORMULAE PER 4 OXYGENS

Si^{4+}	1.001	1.0	1.000	1.0
Fe^{2+}	.226		.232	
Mg^{2+}	.002		.033	
Ni^{2+}	.008	2.0	.009	2.0
Mg^{2+}	1.761		1.756	
Ca^{2+}	.003		0.0	

Table 10-2. (continued)

B. Pyroxenes

	cpx		opx	
	TCL 1004-41	GHL	TCL 1004-41	GHL
SiO_2	53.58	53.49	55.64	55.14
TiO_2	0.28	0.35	0.0	0.0
Al_2O_3	5.31	5.28	4.14	4.12
Cr_2O_3	0.73	0.67	0.28	0.16
V_2O_3	0.07	0.11	0.0	0.0
FeO	2.79	2.76	7.02	7.29
MnO	0.0	0.0	0.12	0.09
MgO	14.25	14.28	32.05	32.53
CaO	22.23	22.40	0.67	0.60
NiO	0.0	0.04	0.09	0.07
Na_2O	0.69	0.63	0.0	0.0
BaO	0.06	0.0	0.0	0.0
	------	------	------	------
	99.99	100.01	100.01	100.00

STRUCTURAL FORMULA PER 6 OXYGENS

	cpx TCL		cpx GHL		opx TCL		opx GHL	
Si^{4+}	1.931		1.932		1.924		1.911	
$Al(IV)$	.069	2.0	.068	2.0	.076	2.0	.089	2.0
$Al(VI)$	.157		.157		.093		.079	
Ti^{4+}	.010		.012		---		---	
Cr^{3+}	.021		.019		.008		.005	
V^{3+}	.002		.003		---		---	
Fe^{2+}	.084	1.946	.083	2.0	.203	2.0	.211	2.0
Mn^{2+}	---		---		.004		.003	
Mg^{2+}	.765		.769		1.652		1.680	
Ca^{2+}	.858		.867		.025		.022	
Ni^{2+}	---		.002		.003		.002	
Na^+	.048		.044		---		---	
Co^{2+}	.001		.044		---		---	

Table 10-2. (continued)

C. Spinels

	TCL 1004-41	GHL
TiO_2	0.09	0.0
Al_2O_3	54.52	59.35
Cr_2O_3	11.55	8.99
V_2O_3	0.0	0.0
Fe_2O_3	4.46	8.99
FeO	7.27	9.28
MnO	0.12	0.09
MgO	21.32	20.62
NiO	0.43	0.45
ZnO	0.10	0.05
CaO	0.14	--
	------	------
	100.00	100.02

STRUCTURAL FORMULA PER 32 OXYGENS

	TCL 1004-41		GHL	
Ti^{4+}	0.02		0.0	
Al^{3+}	13.37		14.36	
Cr^{3+}	1.90	15.99	1.46	16.00
V^{3+}	---		0.0	
Fe^{3+}	0.70		0.18	
Fe^{2+}	1.26		1.59	
Mn^{2+}	0.02		0.02	
Mg^{2+}	6.61	8.00	6.31	8.00
Ni^{2+}	0.07		0.07	
Zn^{2+}	0.02		0.01	
Co^{2+}	0.02		0.0	

Table 10-3. Calculated Equilibration Temperatures (T°C) for
Spinel Lherzolites from the Intermontane Belt.

	(1) SELKIRK CONE,YUKON	(2) TELEGRAPH CREEK, B.C.	(3) CASTLE ROCK, B.C.	(4) GRIZZLY HILL, B.C.
12 Kbar				
*K_1	1120	1039	1272	1041
*K_2	1304	1366	1261	1318
16 Kbar				
*K_1	1151	1066	1308	1069
+K_1	1126	1010	1301	1013
*K_2	1323	1381	1281	1336
+K_2	1246	1299	1208	1258
#†K_3	1275	1246	1324	1146
#K_3	1309	1267	1388	1137
0-40 Kbar				
#K_1	962	878	1095	878

(1) Sinclair, Tempelman-Kluit, Medaris (1977) for mineral
    analyses of 2 Lherzolite nodules in Pleistocene cinder
    cone, central Yukon
(2) Stikine region: Lherzolite nodule from Miocene or
    younger basalt flow at Telegraph Creek, B.C. Sample TCL
    1004-41 from H. Greenwood
(3) Littlejohn and Greenwood (1974) for mineral analyses
    from 4 Lherzolite Nodules in Quaternary AOB breccia at
    Castle Rock (Stikine Region) on northern edge of
    Klastline Plateau
(4) Central B.C., Lherzolite nodule from Miocene basalt
    dyke at Grizzly Hill Hamilton (1979)
 † Wells (1977)
    $10^4/T°K = -1.362 \ln k + 4.570 + 3.324$ Fe/Fe + Mg (opx)
    Of the natural compositions he tests this on,
    lherzolites and peridotites give the largest T°K
    discrepancies compared to other mineral geothermometers.

of the reported mineral data. The calculated temperatures
fall in a tighter range than for previously reported values.
Taking the Telegraph Creek, Castle Rock and Selkirk values
as representative of the Upper Mantle beneath the Northern
Cordillera in the vicinity of Level Mountain, the three
mineral thermometers (k_2, k_3) give values in the range 1200°
to 1400°C at 12 to 16 kbar, while the pyroxene thermometers
give lower estimates of 875° to 1300°C. Using a surface
temperature estimate (5°C), the average of all 12 kbar
estimates (1219°C), and the average of all 16 kbar estimates
(1228°C) for each locality, results in geothermal gradients
in the range of 25°/km (82.4°/kbar) down to the intersection
with the lherzolite solidus, see Figure 10-1. Owing to the
Cr content of these natural samples, this geothermal
gradient estimate is probably a maximum. For the simple four
component experimental analog of the lherzolite system
(CMAS)[1]this intersection would be at 15.8 kbar (51.8 km).
Considering the effect of other components such as alkalis,
iron, titanium, phosphorous and volatiles in depressing the
solidus, this intersection is likely to be even shallower
(see pyrolite solidus of Green and Ringwood, 1967). If some
of the higher geothermometry estimates are accurate, the
geotherm could be as steep as 31°/km with a solidus
intersection as shallow as 41km (12.5 kbar). On the basis of
trace element data, all of these spinel lherzolites appear
to be high temperature refractory residua from previous
----
[1]$CaO - MgO - Al_2O_3 - SiO_2$

Figure 10-1.
P-T plot showing phase fields and solidus for mantle peridotite along with liquidus data for basaltic lavas and range of PT estimates for lherzolites from northern Cordillera.
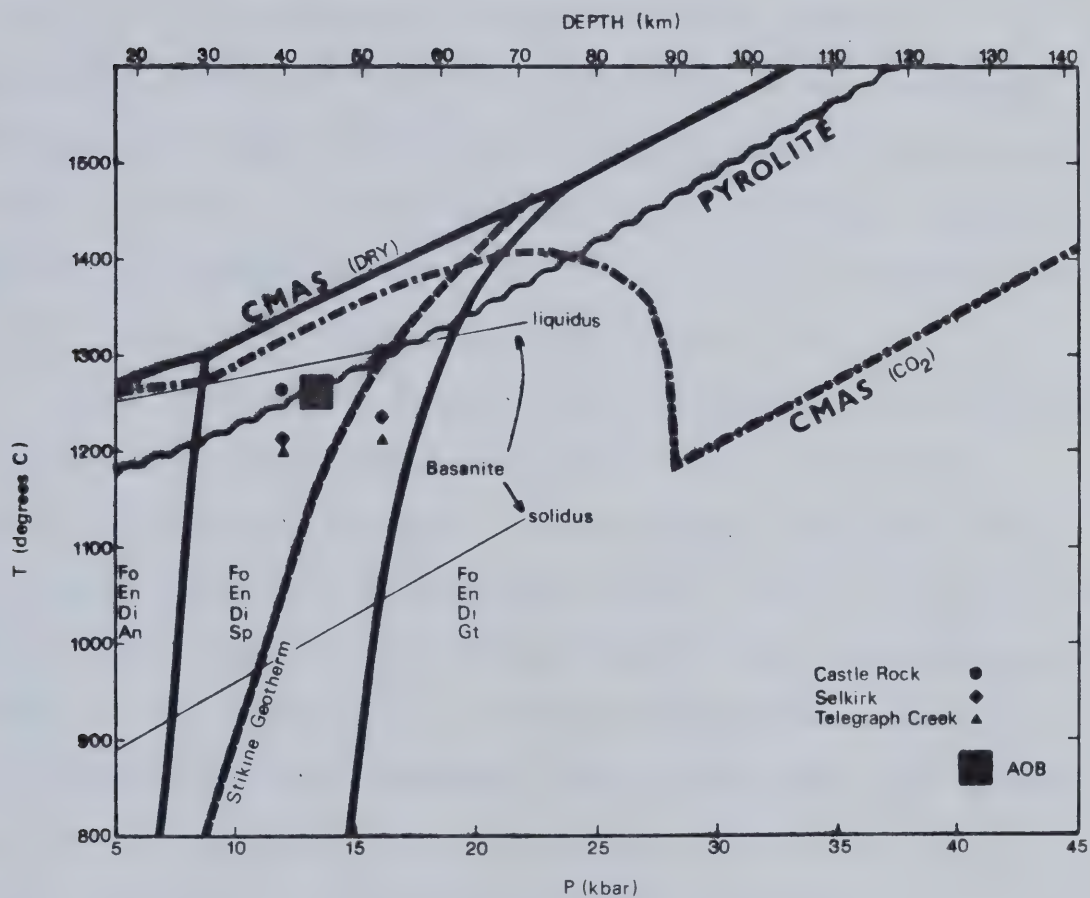
partial melting events and they are too depleted to be source rocks for normal basalt genesis.

For comparison with natural rock systems the melting relations (solidus and liquidus) of a basanite are shown in Figure 10-1. The basanite comes from Mount Shadwell, Australia (Arculus, 1975). The intersection of the basanite solidus with the hypothesized Stikine geotherm lies in the stability field of ol + Cpx + Sp + Pl + L and the liquidus - geotherm intersection is in the field of ol + L, according to the phase relations of Arculus (1975).

From the work of DePaolo (1979) the intersection of the liquidus of an AOB having log a SiO_2 = -0.4 with the anhydrous pyrolite solidus, is at 13.5kbar (44.5km). This point marking the alkali olivine basalt depth of origin lies within the field of the northern Cordilleran geothermometry estimates and slightly to the high temperature side of the hypothesized Stikine geotherm. Using these data the melting region for generating the Stikine basic lavas can be approximated to lie between 36 and 50 km depth.

GEOBAROMETRY AND GEOTHERMOMETRY FROM THE ACTIVITIES OF SILICA AND ALUMINA IN LEVEL MOUNTAIN LAVAS

Expressions for the variation of log $aSiO_2$ into the melt with temperature have been published by Carmichael et al (1970) and for temperature and pressure by Nicholls et al (1971), Nicholls and Carmichael (1972) and Bacon and Carmichael (1973). The basic assumption is that for the

coexistence of minerals and silicate melts at equilibrium, the compositions of the minerals define a buffer on the activity of SiO_2 into the melt. Thermodynamically this can be stated:

$$U^\circ{}_{SiO_2}^{melt} + RT \ln a_{SiO_2}^{melt} = U^\circ{}_{SiO_2}^{minerals} + RT \ln a_{SiO_2}^{minerals}$$

and for more than one solid phase the right hand size would contain additional activity terms. If the chemical potential of silica in the standard state is taken to be that of SiO_2 glass for both melt and crystals, then the activity terms are equal. The activity of silica into the melt (or solids) may be defined by:

$$\left[\log a_{SiO_2}^{melt}\right]_{P,T} = \frac{\Delta G^\circ}{2.303RT} + \frac{\Delta V^\circ}{2.303RT}(P-1) + \log K$$

\# where $\Delta Cp = 0$ and K is the equilibrium constant for the reaction in question, defined by stoichiometry, and the activity terms are for pure mineral components into actual crystal phases, after Bacon and Carmichael (1973). Examples of such reactions that buffer silica are:

$$SiO_2(melt) = SiO_2(\beta \text{ Quartz})$$

$$\text{and } Mg_2SiO_4 + SiO_2(melt) = 2MgSiO_3$$
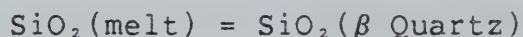
after Nicholls et al (1971). Note that in using real mineral compositions, the activity depends on both the solution model assumed and the stoichiometry. The thermodynamic form of the silica activity stated above gives rise to a unique expression for each reaction of the general form:

$$\left[\log a^{\text{melt}}_{\text{SiO}_2}\right]_{P,T} = (A/T + B) + (C/T(P-1)) + \log K$$

In keeping the same form, it can be seen that A and B come from the free energy term, while C comes from the volume change. Values of A,B and C have been calculated from existing thermodynamic data for the various silica buffering reactions. In the absence of a mineral-melt reaction which defines (buffers) the activity of SiO_2 into the melt, the following expression is used

$$\left[\log a^{\text{melt}}_{\text{SiO}_2}\right]_{P,T} = \left[\log X^{\text{melt}}_{\text{SiO}_2} + \frac{\psi(\text{SiO2})}{T}\right] + \frac{V-V^\circ}{2.30RT}(P-1)$$

after Bacon and Carmichael (1973). The V term is evaluated using the partial molar volume data of Bottinga and Weill (1970). The other term is a function of composition

where $X^{\text{melt}}_{\text{SiO}_2}$ is the mole fraction of silica into the melt,

and the composition function is defined:

$$\phi(\text{SiO}_2)/T = \log\left[a^{\text{melt}}_{\text{SiO}_2} / X^{\text{melt}}_{\text{SiO}_2}\right]$$

The function $\phi(\text{SiO}_2)$ may be evaluated at any single temperature if the activity of SiO_2 into the melt is known Nicholls et al (1971) and Bacon and Carmichael (1973) have evaluated the activity of SiO_2 at the quench temperature of a lava. For this purpose they used T quench and log fO_2 from Buddington and Lindsley's (1964) Fe-Ti oxide data, and equilibrium groundmass mineral compositions for olivine and

titanomagnetite with the fayalite-magnetite-silica buffer. The buffer expression is:

$$\log a_{SiO_2}^{melt} = A/T + B + \log a_{Fa}^{ol} + 1/3 \log fO_2 - 2/3 \log a_{Mt}^{TiMt}$$

Note the reciprocal dependance on T and log fO_2. A small error in estimating T and/or log fO_2, while it changes the one bar activity into the melt, does not have as great an effect on estimating $\phi(SiO_2)$ for the lava. The confidence of $X(SiO_2)$ depends only on the accuracy of the bulk chemical analysis.

Alumina activities are evaluated in a parallel fashion for mineral reactions that buffer Al_2O_3. For the unbuffered case, log aAl_2O_3 into the melt must be evaluated at some known temperature to get at ϕAl_2O_3. In basic and intermediate lavas a useful defining reaction is:

$$CaMgSiO_6(cpx) + 1/2\ SiO_2(melt) + Al_2O_3(melt)$$
$$= CaAl_2SiO_8(plag) + 1/2\ Mg_2SiO_4(ol)$$
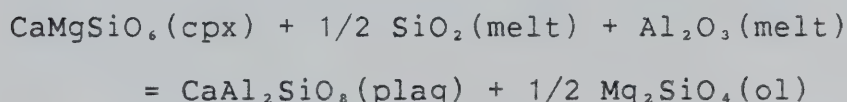
where the equilibrium groundmass assemblage is used and log $aSiO_2$ into the melt must be known. The expressions

$$\log a_{Al_2O_3}^{melt} = A/T + B + \log\left[a_{An}^{pl}\ (a_{Fo}^{ol})^{1/2} / a_{Di}^{cpx}\right] - 1/2\log a_{SiO_2}^{melt}$$

and

$$\phi Al_2O_3 = \left[\log a_{Al_2O_3}^{melt} - \log X_{Al_2O_3}^{melt}\right] T$$

are evaluated using published values for A,B (Bacon and Carmichael, 1973) and compositions data for a specific basalt and its constituent mineral phases.

The variation of mineral-melt buffers for $aSiO_2$ and aAl_2O_3 are shown with temperature and pressure in figure 10-2. These diagrams have been constructed using the data of Bacon and Carmichael (1973), Nicholls and Carmichael (1972) and Nicholls et al (1971). Judging from common phenocryst assemblages, these curves likely span the $aSiO_2$ and aAl_2O_3 ranges commonly encountered for igneous melts from basalts to rhyolites. The unbuffered curves shown for basalt are for examples from Level Mountain. While the convergence of the common silica buffers at high temperature limits the applications of log $aSiO_2$ into the melt as a geothermometer, the strong pressure dependence for the mineral-melt buffers compared to unbuffered lavas lends itself to use as a geobarometer. Log $aSiO_2$ varies inversely with pressure, while log aAl_2O_3 varies directly. The use of silica and alumina buffers together improves the precision of pressure estimates.

Having defined the unbuffered variation in log $aSiO_2$ and log aAl_2O_3 into the melt as a function of P and T for a given lava, the expressions for both log $aSiO_2$ and log aAl_2O_3 may be solved simultaneously with reactions that define the activities of those components in the melt for mineral buffers, using assumed or analysed phenocryst or mantle assemblages, to give unique curves in PT space. As an example, Bacon and Carmichael (1973) solve the forsterite-enstatite buffer for SiO_2 (defined previously) and the alumina buffer given by

Figure 10-2.
Calculated alumina and silica activity mineral-melt buffer
curves. Pure phases unless otherwise shown. Data from
Nicholls and Carmichael (1972) and Carmichael (1973).

$$Mg_2SiO_4(ol) + Al_2O_3(melt) = MgAl_2O_4(sp) + MgSiO_3(opx)$$
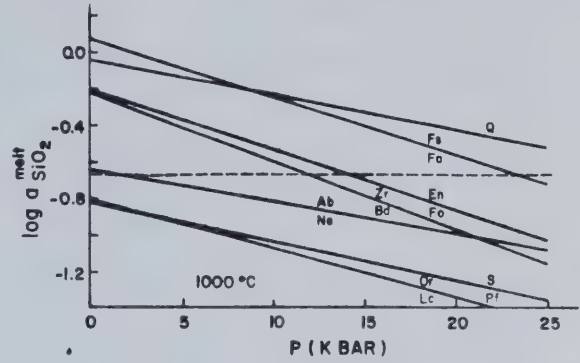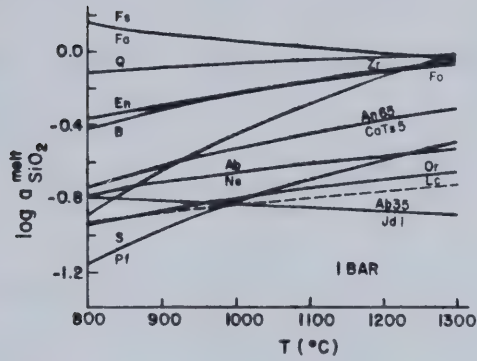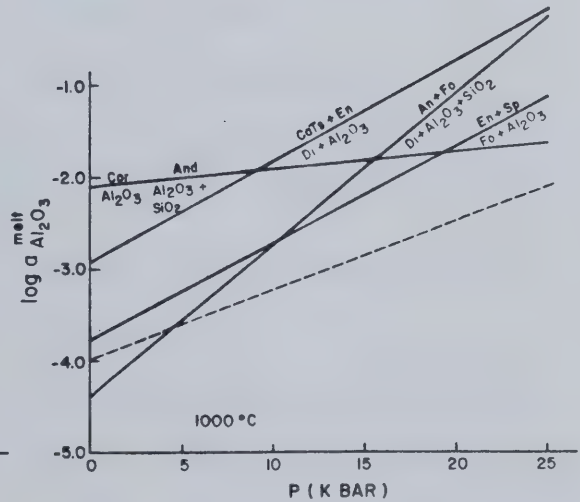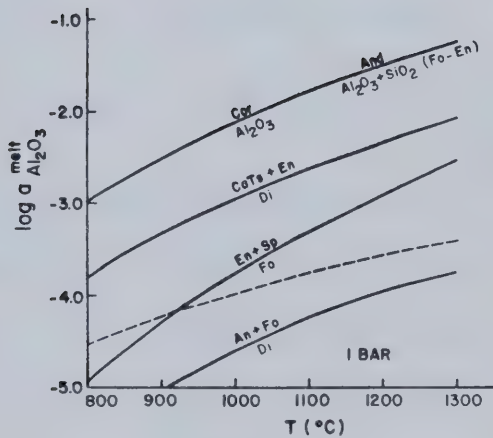
with the unbuffered log activity expressions for the lava to
give an assumed P and T of equilibration with mantle
lherzolite. From the joint solution of the expressions for
any mineral assemblage buffer, the general P-T curve is
given by:

$$(P-1) = \frac{(B - logX(SiO_2) + log\ K)T - (\phi SiO_2 - A)}{D + ET}$$

where T is in °K, P in bars, A,B and K refer to the
particular mineral-melt buffer and D+ET comes from the
difference in the C coefficients for unbuffered melt and the
chosen buffer reaction. In the case of the
forsterite-enstatite buffer this expression is:

$$(P-1) = \frac{(0.597 - logX(SiO_2) + log\ K)T - (\phi SiO_2 + 1034)}{0.0377 + 1.34 \times 10^{-6}T}$$

where log K depends on the composition of olivine and
pyroxene in the lherzolite. Similarily the
olivine-orthopyroxene-spinel alumina buffer and the log
alumina activity expression for the unbuffered melt can be
solved to give:

$$(P-1) = \frac{(2.632 + log\ K - log\ X(Al_2O_3))T - (\phi Al_2O_3 + 8131)}{0.462 - 0.67002 \times 10^{-4}T}$$

where log K is given by:

log K = log a(Sp in sp) + log a(En in opx) + log a(Fo in ol)

The equilibrium P-T curve for the lherzolite can also be
defined by the reaction:

$$CaAl_2SiO_6 + Mg_2SiO_4 = CaMgSi_2O_6 + MgAl_2O_4$$

and $-\log K = -2156/T + 0.869 - 0.00778(P-1)$

The geobarometry of salic lavas presented in Nicholls et al (1971) depends on the simultaneous solution of two mineral-melt silica buffers. The fayalite-magnetite and quartz-silica buffers were used for a variety of acid lavas from different localities including a pantellerite from Pantelleria with P eq. > 7.3 kbar.

Following the method described above, similar geobarometry calculations have been attempted for a few representative lavas from Level Mountain. The data used in these calculations and the results are presented in table 10-4. The quench temperatures inferred here are generally less than or equal to solidus estimates for Level Mountain lavas of similar composition. The oxygen fugacity inferred is slightly greater than or equal to that of the melting experiments. buffers for FMQ and MW by gas mixing.

While no lherzolite inclusions were found in the Level Mountain lavas proper, lherzolites have been found in similar lavas from the Selkirk Cone (Sinclair et al, 1978), Castle Rock (Littlejohn and Greenwood, 1974) and at Telegraph Creek. The mineral compositions from those localities have been used with Bacon and Carmichael's data for

$CaAl_2SiO_6 + Mg_2SiO_4 = CaMgSi_2O_6 + MgAl_2O_4$

to give the following lines in PT space for the spinel lherzolites from the Northern Cordillera (for T in °K and P in bars).

Table 10-4 Geothermometry and Geobasometry Estimates for Level Mountain Lavas

Sample ID	T quench 1 bar °C	log fO2	X plag An	X ol Fo	X ol Fa	X cpx Di	X cpx En	X cpx cats	Timt X mt	log a SiO2	X SiO2	Ø SiO2	log a Al2O3	X Al2O3	Ø Al2O3	P Kbar	T °C	°C/km	Phenocryst Megacryst or Lherzolite used
8/25-50/6397 Hawaiite	985	-11.89	.599 .600	.716 .591	.274 .394	.463	.102	.095	.33	-.6875	.5184	-506 phenos	-3.883 P≤ 5.8	.0982	-3617	10.96 11.98 14.83	883 954 1028	24.56 24.28 21.13	Telegraph Creek Castle Rock Selkirk
PBP 6480 (PBO for some minerals) Hawaiite	975	-12.93	.185 .220	.338 .349 .405	.634 .627 .572	.444	.050	.022	.398 .337 .201	-.6897	.6746	-647 phenos	-4.4173 P≤10.6	.1082	-4308	9.86 9.95 12.37	805 831 900	24.9 25.5 22.2	TCL CR S
PAF 4370 Hawaiite	996	-12.06	.383	.546 .474	.439 .507	.509	.041	.061	.237	-.6109	.5481	-444 phenos	-3.955 P≤10.5	.1075	-3790	9.39 9.52 12.33	914 942 1019	29.64 30.16 25.20	TCL CR S
PAR 4030 Alkali basalt	1050	-10.91	.599	.827	.164	.612	.084	.052	.225	-1.3331	.5087	-1375 phenos	-3.6879 T>1180 P≤ 4.25 Kbar	.0883	-3485	16.54 16.59 19.30	906 932 1000	16.70 17.13 15.80	TCL CR S
PAO 4115 Basalt	1041	-10.42	.526	.773 .707	.220 .281	.607	.076	.047	.386	-.8158	.5354	-715 phenos	-4.1027 (minerals) T<1185°C P<4.9 Kbar	.0956	-4051	14.35 14.40 17.00	803 808 896	17.06 17.11 16.07	TCL CR S
PAX 3675 Basalt	950	-13.00	.557	.762	.230	.467	.084	.052	.240	-1.2446	.5529	-1207.4 phenos	-4.1007 T<1237°C P<9.41 Kbar	.0937	-3758	18.41 18.48 20.93	841 865 931	13.93 14.27 13.56	TCL CR S
PBX 5385 Hawaiite	980	-12.40	.457	.418	.565	.517	.066	.027	(.300)	-.4891	.5358	-273 phenos	-4.7383 T<1150°C P<5.3 Kbar	.0931	-4645	No equil. w/ Lherzolites			No equil. w/ Lherzolites
PAC 4465 Hawaiite	986	-9.13	.457	.540	.444	(.514)	(.044)	(.053)	.819 .944	.2484	.5737	617 phenos	-4.9659 P = 23.8 Kbar	.1027	-5008	No equil. with Lherzolites or phenos?			No equil. with Lherzolites or phenos?
8/26-56/6336 Trachyte	1090	-10.00		.753					.235	.0974	.7076	337.5				6.1 Kbar Q - SiO2/Fa Mt-SiO2			
8/7-19/5830 C.Trachyte	1110	-10.00		.726					.15	.1074	.7500	321.3				6.5 Kbar Q - SiO2/Fa Mt SiO2			
8/30-82/6150	860	-13.86	.232	.394	.574	.435		Jd=.04	.436	-.3716	(.7224)	-261	-5.6133	(.0967)	-5210	6.4 Kbar Ab--Jd/Fa Mt SiO2			

Telegraph Creek: P = 175.94 T - 277122
Castle Rock: P = 195.71 T - 277122
Selkirk: P = 187.31 T - 277122

The Castle Rock assemblage gives a very similar slope
($\Delta P / \Delta T$) to the San Quentin lherzolites of Bacon and
Carmichael (1973), while the slopes for Telegraph Creek and
Selkirk are slightly less. Graphical presentation of the P-T
solutions for a basalt from the base of the Level Mountain
plateau (unit 1) and a hawaiite from the central stratocone
(unit 8) are given in Figure 10-3. Not only do these
examples span most of the time of the Level Mountain
volcanism, but they also span the range of depth estimates
for the basaltic lavas. Two of the hawaiites presented in
the table do not have real solutions (lying in positive P-T
space) for lava-lherzolites or lava-phenocrysts. Those two
hawaiites are assumed to be derived by substantial
fractional crystallization from more primitive compositions,
and in their final erupted compositions are likely to be out
of equilibrium, with respect to silica and alumina activity
for their phenocrysts and their presumed mantle source. As
with the San Quintin lavas presented by Bacon and
Carmichael, there may be some problems with the calculated
pressures and temperatures. For the Level Mountain basaltic
lavas all of the pressures fall into the spinel lherzolite
stability field, but the temperatures seem too low for
genesis of basaltic magmas. The pressures are similar to
those calculated for other alkaline lavas from the

Figure 10-3.

Calculations of P-T equilibration conditions for spinel lherzolites from the northern Cordillera and two Level Mountain lavas. Upper set of 3 subparallel curves are for spinel lherzolites alone, assuming the reaction CaTs+Fo=Di+Sp. The plot on the left for PAX, from the lower plateau, shows the range of equilibration pressures for the unbuffered melt and lherzolite minerals, using all 3 lherzolites. Points are the intersection of $Fo+SiO_2=En$ with $Fo+Al_2O_3=Sp+En$. An estimate of pressure of equilibration for unbuffered melt and phenocrysts is given by the intersection of $Jd+SiO_2=Ab$ for the plagioclase with $Di+SiO_2+Al_2O_3=An+Fo$ for the pyroxene. The plot on the right is for stratocone hawaiite 8/25-50/6397. The pressure estimate for melt equilibration with lherzolite minerals is lower. The lower of the pairs of curves for phenocryst buffers (with negative slope) is for $CaTs+SiO_2=An$ other reactions as before. T= Telegraph Creek, S = Selkirk, CR = Castle Rock.
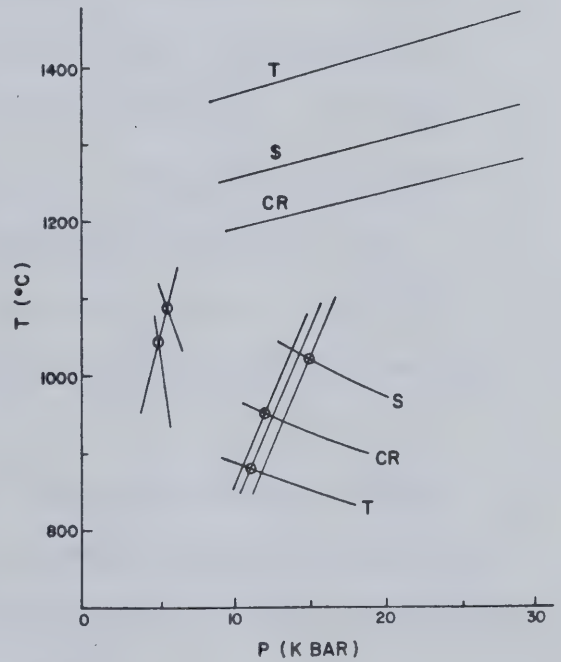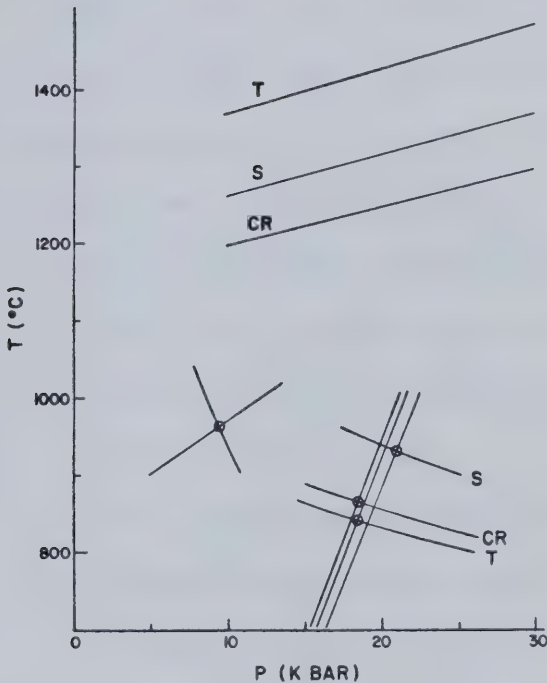
Intermontane Belt (Fiesinger and Nicholls, 1977); Nicholls et al, 1981 in prep.). The pressures calculated for three salic lavas from Level Mountain are all in the range from 6.0 to 6.5 kbar. This corresponds to the average depths calculated for diverse salic lavas in Nicholls et al (1971). The uncertainty associated with the depth (pressure) estimates for Level Mountain salic lavas is far greater than for the basalts. The two reasons for this are that the fayalites for these lavas were in reaction (petrographically) with their respective groundmass compositions (as judged by riebeckite or sodic pyroxene overgrowths), and the mineral buffers used to calculate depths were only assumed to be in equilibrium with said lavas, and this may not have been the case. The salient features of these calculations for Level Mountain are

1. that most of the basalts could have been in equilibrium with a spinel lherzolite mantle at pressures in excess of 9.4 kbar

2. that phenocryst assemblages from most basalts imply crystallization in the 4 to 6 kbar region, which could indicate the existence of crustal level magma chambers and

3. that salic lavas could have come from the lower crust or upper mantle according to the silica activity geobarometry calculations for three trachytes.

A summary of the geobarometry calculations for Level Mountain lavas is presented in Figure 10-4, with pressure

presented versus elevation (eruptive sequence) of the flows.
The implication is that initial plateau volcanism originated
at pressures from 18.5 to 21.0 kbar and subsequent lavas
were derived from shallower depths. There is an indication
of an upward migrating melting zone with time. This would be
consistent with expectation from experimental studies on the
spinel lherzolite system (Takahashi and Kushiro, 1981;
Presnall, 1980; Ito and Kennedy, 1967). Following the
reasoning of Presnall (1980), for a CO_2 bearing upper
mantle, a rising geothermal gradient would intersect the
lherzolite solidus cusp in the region of 20 kbar and remain
there until one phase was exhausted (generally
clinopyroxene). Subsequently the geotherm is constrained by
the geometry of the spinel lherzolite solidus and a period
of rising depth of melting could occur in a short time span,
until the geotherm intersects the 10 kbar cusp on the
lherzolite solidus. This sequence of events could have
occurred at Level Mountain with the second cusp being
reached by the time of extrusion for the basalts of the
uppermost plateau (unit 4). The lavas of the stratocone
could represent the further upward migration of the geotherm
and melting zone into the base of the crust, or by
generation of primary magmas at the 10 kbar cusp and further
evolution in crustal level magma chambers.

Takahashi and Kushiro (1981) have found a partial melt
of "phonolite" composition to exist in equilibrium with Fe-
and K-rich spinel lherzolite (Salt Lake Crater, Oahu) at

Figure 10-4.

Geobarometry and geothermometry estimates for equilibration
of Level Mountain basalts with spinel lherzolite using
(Fo-En-SiO$_2$) and (Fo-En-Sp-Al$_2$O$_3$), imply a rising geothermal
gradient and a rising zone of partial melting with time.
Phenocryst equilibration conditions range from the shallow
upper mantle to the lower crust. Trachyte estimates from
(Fa-Mt-SiO$_2$) and (Q-SiO$_2$) imply equilibration in the lower
crust.
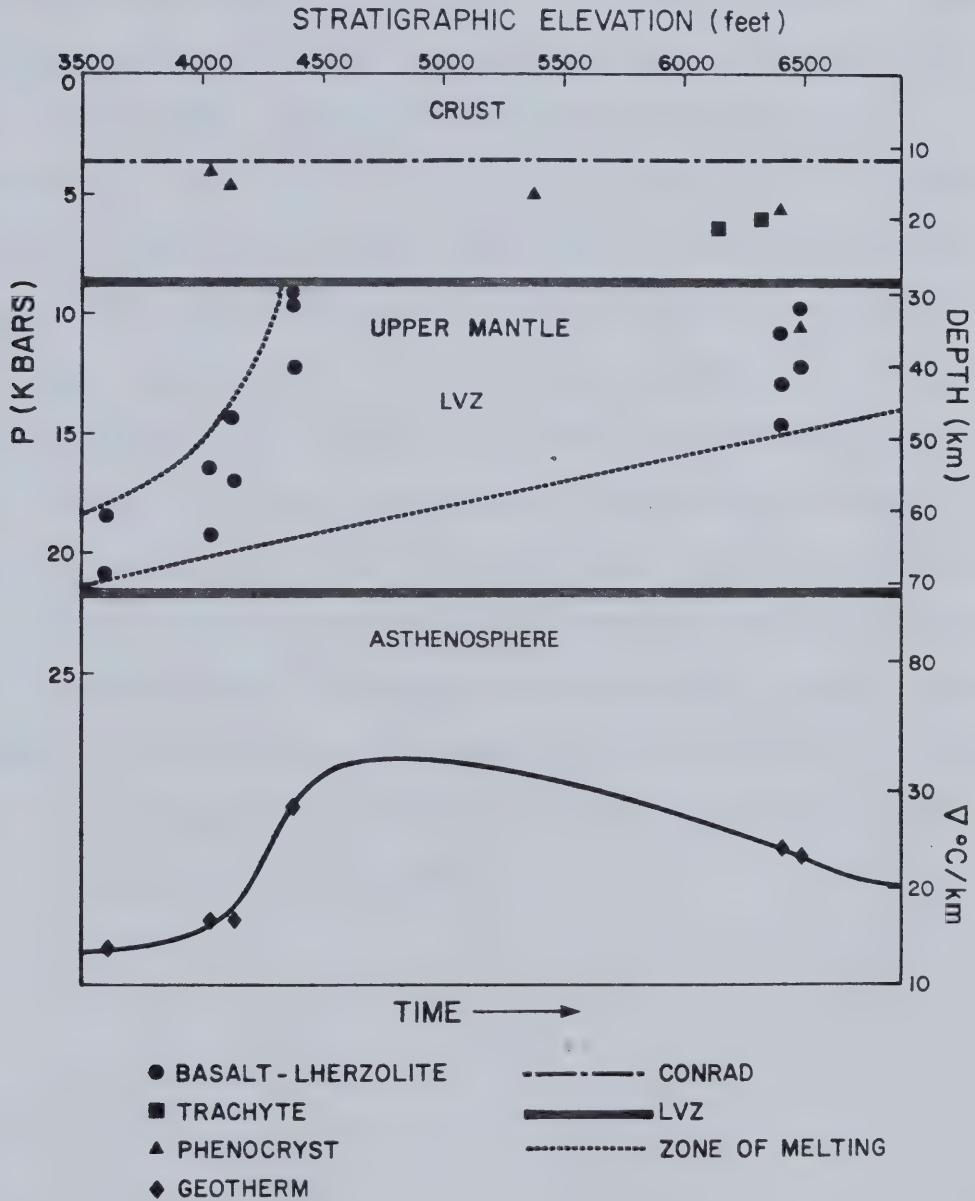
temperatures as much as 200° below the apparent lherzolite solidus (anhydrous). These melts contain in excess of 9.0% by weight K_2O and are effectively peralkaline. This is reminiscient of the bimodal melting hypothesis of Yoder (1976). As the stratocone lavas from Level Mountain include phonolites and are dominantly peralkaline, the possibility still remains that they could be directly generated at mantle depths. Takahashi and Kushiro (1981) also performed a variety of "pyrolite" type experiments involving basaltic glass sandwiched between peridotites (spinel lherzolites). They found that plagioclase - pyroxene gabbros crystallized below the lherzolite solidus and were apparently stable in the PT field for spinel lherzolite. Should significant portions of such alkaline gabbros remain behind in the upper mantle they could contribute to the mantle differentiation and to compositional variation of subsequent partial melting episodes . The existence of gabbroic compositions at mantle depths could possibly account for the peralkaline salic lavas of the stratocone stage.

CHAPTER 11. A PALEOMAGNETIC STUDY OF THE LEVEL MOUNTAIN VOLCANICS

INTRODUCTION

Paleomagnetic studies have been conducted both on Mount Edziza (Souther and Symons, 1974) and on Level Mountain (Evans and Hamilton, 1980). At Level Mountain fifty cooling units were collected from two stratigraphic sections, Figure 11-1. The composite thickness of the proximal and distal sections is greater than 1000 meters. Fourteen magnetic polarity zones are found to be present as well as several low latitude virtual geomagnetic poles (VGP's) which probably represent transitions or excursions. A combination of magnetic data, stratigraphy and fission track dates indicates that the time span of Level Mountain volcanism extends from Epoch VII (greater than 6MY) to the Brunhes Epoch (less than 1MY). This will be shown to be similar to the results from Edziza.

Most sites carry a stable remanence (TRM), which can be determined with high precision. Fisher's precision parameter k generally exceeds 100. The two stratigraphic sections include several low latitude VGP's that probably represent polarity transitions or geomagnetic excursions. Filtering out the sites with low-latitude VGP's (N=5) and high internal scatter (N=7) leaves thirty-eight site means, twenty-four of which have normal polarity and fourteen of which are reversed. The average normal direction does not

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Figure 11-1.

Location of the two paleomagnetic sections are shown on the
geological sketch map of the Stikine Plateau: showing Level
Mountain range and location of related Late Cenozoic
volcanics.
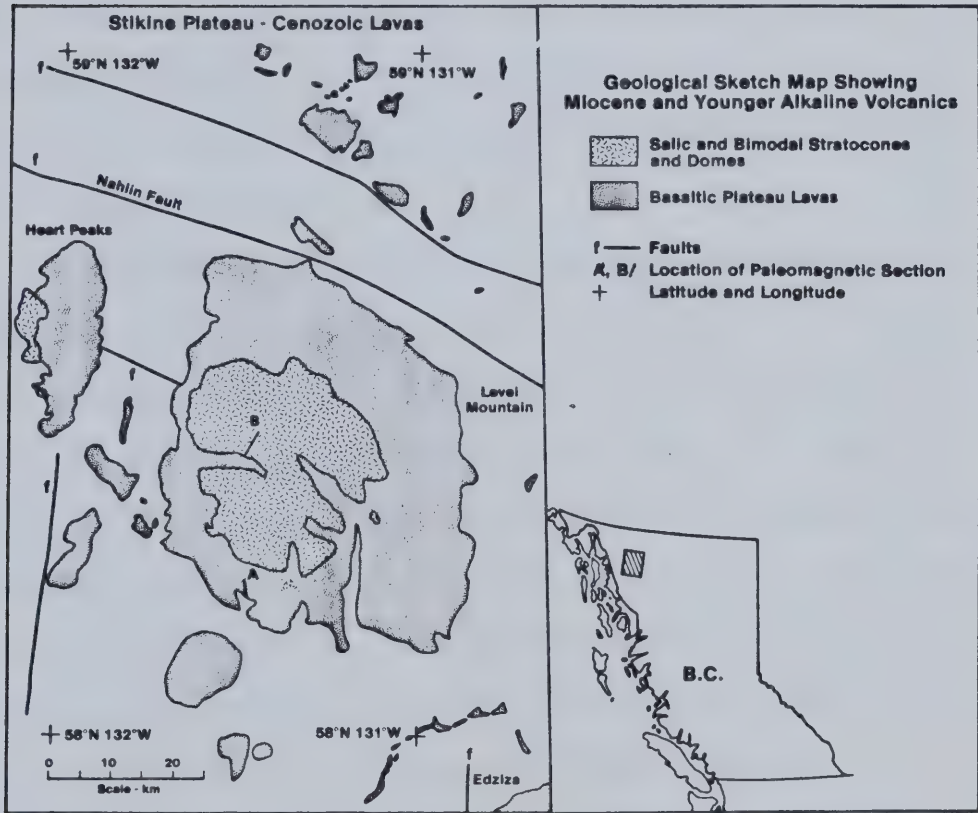
differ significantly from the inverted reverse direction,
and the overall mean yields a paleopole at 85°N lat. 256°E
long., with an A,, of 7°. The actual mean paleopole is
slightly near-sided in terms of the common site longitude
convention, which fails to support Wilson's eccentric dipole
model (Wilson, 1972). Instead near-sidedness seems to be a
persistent characteristic of paleopoles obtained from
Western North America, suggesting the presence of a long
term non-zonal anomaly.

The paleopole position for the best thirty-eight sites
at Level Mountain includes the present spin axis as does the
Edziza paleopole and the paleopole for the combined Stikine
data sets. Since the circles of confidence for these
paleopoles include the spin axis, any Late Cenozoic tectonic
movements for the Stikine Terrane would appear to be small.
The primary purpose of this study was to establish a
magnetic stratigraphy for Level Mountain in hopes of
correlating to the previously published magnetic
stratigraphy of Edziza (Souther and Symons, 1974). An
additional incentive was to seek information concerning the
overall morphology of the geomagnetic field and its change
with time. In this regard, the Late Cenozoic age and high
latitude location of Level Mountain are particularly
important. The rock magnetic properties of the samples were
also investigated to document possible correlations between
magnetic and petrological characteristics.

METHODOLOGY FOR THE PALEOMAGNETIC STUDY OF LEVEL MOUNTAIN

Field Procedures. Two stratigraphic sections of twenty-five flows each were collected. Five to seven cores were sampled, from each of the 50 flow-cooling units for a total of 252 cores. With three exceptions all of the flows were collected from contiguous stratigraphic sections. In these cases PBT, PBX, and PAF either exposure or access required that flows be projected "line of sight" back into the main section.

The PA section (distal and stratigraphically lower) was collected from the east facing canyon wall of the Little Tahltan River on the Southern Plateau margin at approximately 58.25°N 131.50°W, Plate 11-1. The section crosses 280 meters of vertical relief which spans the first four eruptive units (1-4) encompassing the plateau building stage at Level Mountain.

The PB section (proximal and stratigraphically higher) was collected from the South face of Meszah Peak and the south trending hanging valley which drains into the Kakuchuya Creek at approximately 58.49°N and 131.48°W, see plate 11-2. This section crosses 700m of vertical relief spanning the stratocone eruptive units 5 to 9. There is a 134m elevation gap between the two stratigraphic sections, which are separated by a lateral distance of 23km. According to field mapping there is no stratigraphic overlap between the two sections, but little or no section is inferred to be missing. The preferred interpretation is that the 134km elevation gap reflects the slope of the plateau surface

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Plate 11-1.

The PA section through the basaltic flows of the Level
Mountain was collected from the canyon wall of the Little
Tahltan river, site PAA to upper right, site PAY lowest dark
flow in stream notch above tree line. Map unit 1 extends
from base of section to top of dark flows low on cliff. Map
unit 2 is lighter coloured with thin flows. Map unit 3
comprises dark flows and tuffs to top of notch. Map unit 4
rests on a thick light coloured tuff unit that lies along
the top of the cliff.
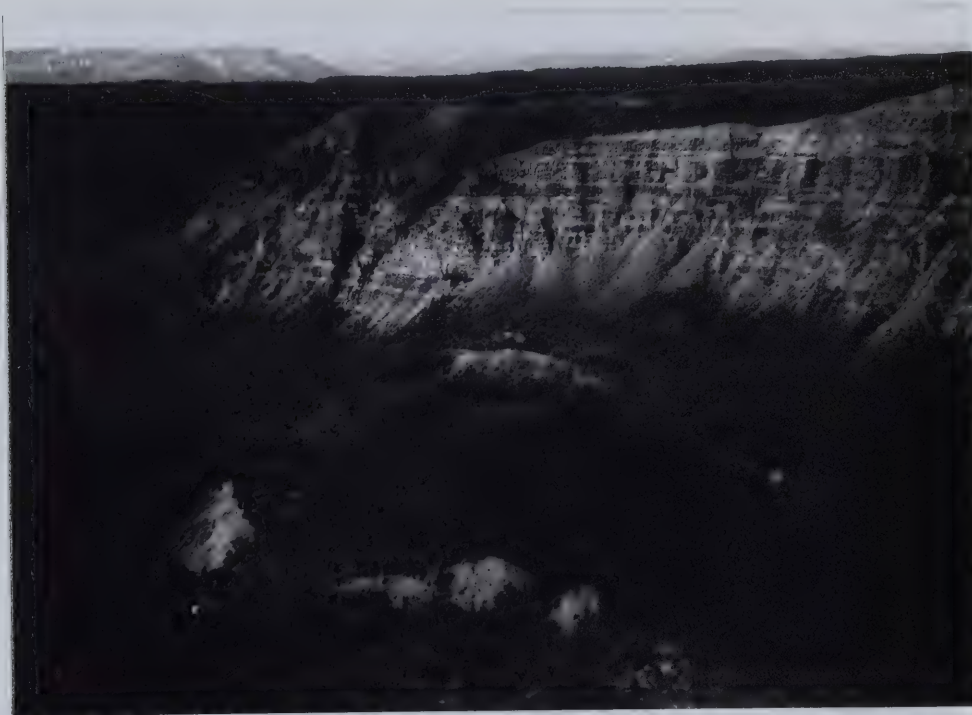
Plate 11-2.
View to SW along Hanging Valley from summit of Meszah Peak.
The PB section through the stratocone followed the creek,
down the hanging valley into the lower valley of Kakuchuya
Creek.

(0.33°).

Laboratory Methods. The general measurement techniques to obtain the remanence vector for rock samples have been reviewed by McElhinny (1973) and Cox et al (1967). Pilot measurements of the magnetic vectors were made on a Princeton Applied Research Spinner magnetometer model SM-1 interfaced to a Wang 600 programmable calculator. The stability of one specimen from each flow was tested by routine alternating field (AF) techniques, mostly in peak fields of 2.5, 5, 10, 20, 40 and 80 mT. The results were used to identify regions of directional stability, and thus to select appropriate treatments for the remaining specimens. The bulk of a lab work was conducted using the Schonstedt SSM-1 interfaced to the Wang. The entire study involved about 1100 remanence measurements (presented in Appendix 3). Only one specimen from each core was measured as it has been demonstrated by Doell and Cox (1963, 1965) that very little additional accuracy is gained by multiple sampling. Each specimen was measured for natural remanent magnetization (NRM) and stepwise demagnetized to find a best estimate of D and I for each site. The stepwise demagnetization was performed in an alternating field (AF) apparatus designed and built by Murthy (1969). Due to the variation in rock types and rock magnetic properties a blanket treatment could not be prescribed for all sites. The minimum dispersion criterion (Irving et al, 1961) was applied to identify the best estimate of the mean remanence

direction at each site. Means were calculated in a
hierarchial fashion. The values of D and I corresponding to
the lowest value of $\alpha_{,5}$ (highest Fisher k) were selected
from among the sets of measurements at each site. In no case
were fewer than three specimens from different cores finally
selected to yield a D and I, and in most instances all cores
could be used with no rejections. At nine sites one or two
specimens exhibited anomalous behavior, either by
systematically approaching the group formed by companion
cores but never quite reaching this goal, or by stubbornly
retaining a divergent direction. These specimens were
excluded from further analysis, but it is noteworthy that
they represent only 5% of the total data set. Although in
part subjective, it is felt that this procedure yields the
best available estimate of the true mean paleomagnetic
vector at each site. A series of field and laboratory notes
have been prepared site by site in descending stratigraphic
order as a reference for this collection of data and to
clarify any peculiarities at a given site. These notes are
presented in Appendices 1 and 2.

The directional variance within each unit is generally
small, with Fisher's precision parameter (Fisher, 1953)
k>100 in 34 out of 50 flows, and k <50 in only 7 cases.
Another convenient measure of the quality of the directional
data is provided by the angular shift occurring at the
demagnetization step used in the final analysis. When sites
with poor internal grouping are excluded, as explained

below, these angular shifts are quite small. Sixty-seven
percent of specimens undergo a shift of 3° or less, the
corresponding values for <5° and <10° being 79% and 92%
respectively. Thus a small fraction of the specimens have no
direct evidence of end-points, and their inclusion rests on
agreement with cores from the same site, as reflected by the
appropriate site statistics.

MAGNETOSTRATIGRAPHY FOR LEVEL MOUNTAIN

The Stratocone Section, (PB)-Meszah Peak

The essential magnetostratigraphic information for
Level Mountain is summarized in Table 11-1. The variation of
VGP latitude as a function of elevation is presented as a
magnetogram in Figure 11-2.

It is evident that the stratocone section (PB) spans at
least three polarity zones. In order of increasing age these
are normal, reversed, normal. The uppermost normal
magnetozone, stratigraphically map unit 9, comprising
hawaiite flows at the summit of Meszah Peak, can confidently
be regarded as sampling the Brunhes (Epoch 1). These flows
are the most recent on Level Mountain and field relations
indicate that they postdate Quaternary continental
glaciation (according to field mapping performed by the
author and observations of Ostensoe, 1960).

Sites PBP down through PBL are clearly reversed. The
most straightforward correlation with the established

Table 11-1 Level Mountain Paleomagnetic Remanence Data by Sites

Unit	Site	Elev	Dens	% NRM	AF	n	R	k	α95	D	I	LAT	LONG
9	PBT	7250	2.89	8.8	400	3(2)	2.9881	168	9.5	32.7	78.9	72.2	270.3
9	PBS	7200	2.96	0.5	800	3(2)	2.9932	294	7.2	45.5	55.1	52.7	336.7
9	PBR	6625	3.00	12.9	200	5	4.9378	64	9.6	51.7	61.9	55.0	322.1
9	PBQ	6580	2.94	4.1	400	3(2)	2.9886	175	9.3	30.4	54.0	59.0	355.9
8	PBP	6480	2.52	83.9	200	5	4.9656	116	7.1	216.0	-73.8	-71.6	119.0
8	PBO	6440	2.54	95.4	100	5	4.9387	65	9.5	184.0	-86.2	-65.5	51.3
7	PBN	6340	2.54	61.0	200	5	4.9983	2352	1.6	262.0	-78.3	-54.3	90.5
7	PBM	6160	2.60	101.0	50	5	4.9891	367	4.0	221.2	-62.3	-60.9	151.5
7	PBL	5835	2.62	79.1	200	5	4.9571	93	8.0	172.3	-65.6	-78.8	257.6
7	(PBY)	5780	2.58	16.4	100	5	4.7744	18	18.7	19.7	30.7	46.0	22.3
7	(PBK)	5745	2.54	100.0	0	5	4.7136	14	21.2	358.4	1.0	32.5	51.9
6b	PBJ	5690	2.80	35.0	100	5	4.9651	115	7.2	28.1	74.1	75.5	298.9
6b	PBI	5675	2.80	38.6	200	5	4.9709	138	6.6	20.2	80.8	73.7	252.3
6b	PBH	5655	2.75	51.8	50	5	4.9917	482	3.5	1.6	79.5	78.3	232.7
6a	PBG	5580	2.48	79.7	200	5	4.9867	301	4.4	19.2	-1.2	(29.4	27.8)
6a	PBF	5545	2.58	57.0	200	5	4.9621	106	7.5	12.4	5.1	(33.7	35.1)
6a	PBE	5475	2.50	78.3	200	5	4.9775	178	5.8	19.3	4.3	(32.1	27.0)
5b	PBD	5460	2.42	98.8	50	6	5.9849	331	3.7	18.7	14.5	(37.3	26.4)
5b	(PBC)	5450	2.78	98.8	100	5	4.8212	22	16.5	353.4	48.8	61.4	62.0
5b	PBB	5430	2.86	9.5	200	5	4.9167	48	11.2	331.8	66.0	70.7	122.1
5b	PBA	5420	2.80	76.2	50	4(1)	3.9968	937	3.0	4.3	53.9	66.3	41.2
5b	(PBX)	5385	2.87	35.8	50	5	4.6887	13	22.2	197.5	-76.8	-79.2	93.1
5a	PBU	5220	2.64	21.1	100	5	4.9351	62	9.8	348.9	72.6	84.1	144.0
5a	PBV	5100	2.26	100.0	0	4(1)	3.9908	326	5.1	8.9	61.8	74.0	25.8
5a	PBW	5000	2.34	46.7	100	5	4.9781	183	5.7	68.4	85.9	60.1	245.4
4	(PAA)	4560	2.87	11.5	400	5	3.9924	4	44.1	167.3	-64.0	-75.5	267.7
4	PAB	4505	2.64	235.4	100	5	4.9884	345	4.1	42.9	81.7	67.3	259.7
4	PAC	4465	2.66	70.4	200	5	4.9841	251	4.8	189.3	-67.3	-80.4	191.5
4	(PAD)	4440	2.63	9.8	400	2(2)	1.9869	76	29.0	169.5	-75.0	-83.5	0.4
4	PAE	4400	2.78	65.6	100	5	4.9978	1818	1.8	313.0	69.3	63.4	149.5
4	PAF	4370	2.58	25.5	100	5	4.9773	176	5.8	294.2	81.7	61.0	198.2
4	PAG	4340	2.66	54.9	100	5	4.9894	377	3.9	280.4	76.9	54.0	185.1
4	PAH	4300	2.56	42.2	100	5	4.9886	351	4.1	15.8	66.7	77.2	356.4
3	PAI	4230	2.70	39.1	200	5	4.9940	667	3.0	63.0	86.2	60.7	243.9
3	PAJ	4200	2.72	19.2	200	5	4.9878	328	4.2	310.1	80.0	66.0	191.3
3	PAK	4170	2.82	24.3	200	5	4.9346	61	9.9	330.7	83.6	68.2	213.2
3	PAL	4155	2.92	15.5	100	5	4.9804	204	5.4	308.6	70.1	61.7	154.6
3	PAM	4135	2.74	46.2	200	5	4.9744	156	6.1	163.2	-45.6	-56.9	258.1
3	PAN	4125	2.82	88.4	200	5	4.9294	57	10.3	169.4	-46.2	-58.6	248.3
3	PAO	4115	2.78	77.0	100	4(1)	3.9986	2141	2.0	167.0	-75.0	-82.5	355.8
3	PAP	4100	2.64	30.1	200	5	4.9317	59	10.1	173.4	-84.4	-69.0	46.5
2	PAQ	4065	2.70	33.1	200	5	4.9916	476	3.5	349.8	60.8	72.6	76.2
2	PAR	4030	2.88	47.1	100	4(1)	3.9957	698	3.5	44.7	57.8	55.3	334.5
2	PAS	3880	2.79	66.5	50	4(1)	3.9914	349	4.9	18.7	69.7	78.6	335.2
2	(PAT)	3860	2.40	108.1	200	4(1)	3.6531	9	33.1	156.6	-77.8	-76.2	8.3
2	PAU	3815	2.80	86.0	200	5	4.9910	444	3.6	154.6	-60.7	-67.2	285.6
2	PAV	3780	2.80	106.0	100	5	4.9259	54	10.5	178.8	-71.8	-88.5	256.5
1	PAW	3700	2.62	54.4	100	5	4.9698	133	6.7	0.0	21.3	(43.0	50.0)
1	PAX	3675	2.78	97.5	100	5	4.9955	889	2.6	147.5	-87.0	-62.9	42.9
1	PAY	3650	2.64	20.4	400	5	4.9770	174	5.8	65.5	-87.5	-55.7	41.9

Notes:
Elev	=	elevation above sea level (feet)
Dens	=	mean density in g/cc for cores from site
% NRM	=	% of NRM intensity remaining upon reaching endpoint
AF	=	field strength of last demag step upon reaching endpoint
n	=	number of cores accepted (rejected)
R	=	vector resultant of n unit vectors
k	=	Fisher's precision parameter
α95	=	half-angle of cone of 95% confidence
D	=	declination
I	=	inclination
LAT	=	latitude of equivalent VGP
LONG	=	longitude of equivalent VGP

Figure 11-2.
Magnetogram for Level Mountain lavas showing polarity (VGP Lat) versus absolute stratigraphic elevation for the two Level Mountain sections. Lines are broken for erosional interval or other indicated time hiatus.
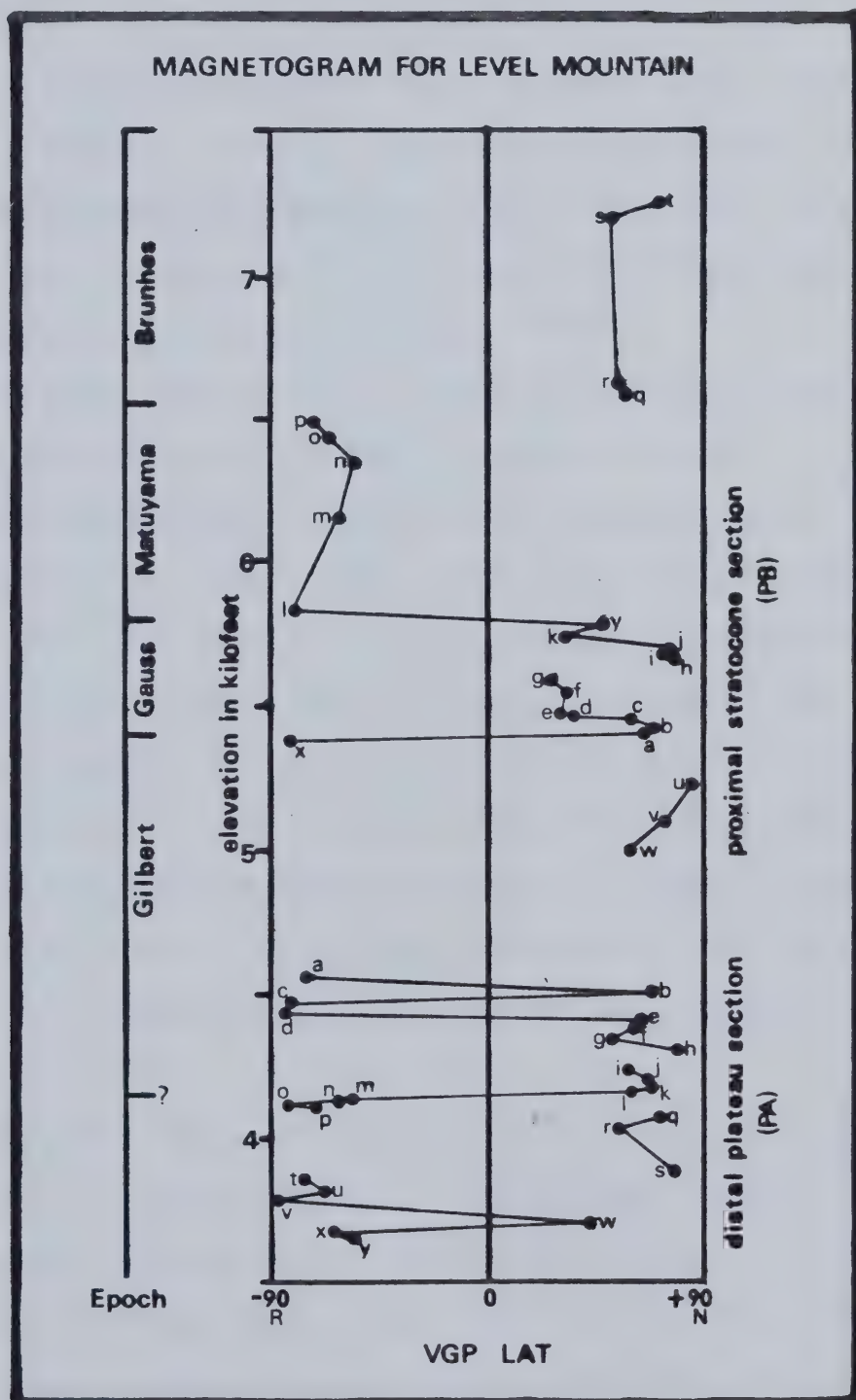
geomagnetic polarity time scale, Figure 11-3, is that these belong to the Matuyama (Epoch 2). It is uncertain whether this sequence of five reversed sites at Level Mountain lies above, below or misses the Jaramillo event entirely. It is not unreasonable to suppose that the short term normal events (Jaramillo, Gilsa, Olduvai) comprising less than 0.3MY (McDougall and Chamalaun, 1966; Cox, 1969) could be missed by a random sampling of only a few flows spread over the length of the Matuyama (some 1.75MY).

Sites PBY and PBK at the base of map unit 6 are normal, but of low precision, and have somewhat shallow inclinations, possibly representing a transition or excursion of the geomagnetic field. Flows at the base of map unit 6 have been dated (by fission track on pitchstones) at two locations on Level Mountain near the head of the Kakuchuya Valley. The dates are 2.61 ±0.12 and 2.46 ±0.12MY (N. Briggs, pers. comm., 1978). These dates coincide within error to the Matuyama/Gauss boundary. It appears that the sequence of flows from PBL down through PBJ samples this transition, with sites PBY and PBK actually lying in the transition itself.

Sites PBJ, PBI and PBH most likely lie in the upper portion of the Gauss (Epoch 3). Below these basalts is a stratigraphic break and a lithological change to peralkaline trachytes. The next four flows have very shallow remanence directions, but the corresponding within- and between-site grouping is good. This group of flows (PBD, PBE, PBF, PBG)

Figure 11-3.
Reference geomagnetic polarity time scale adapted from
Mankinen and Dalrymple (1979) down to the base of the
Thvera, and from MacDougall et al (1977) down into Epoch 7.
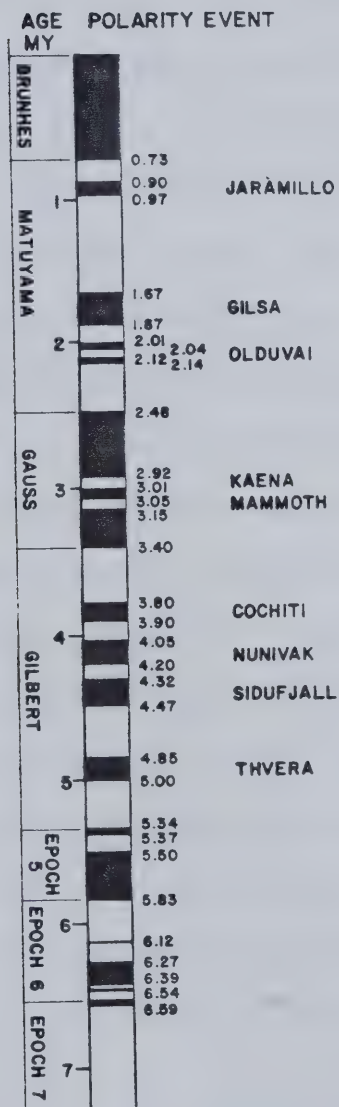
represents either an excursion or a transition from an underlying normal to an unrecorded reversed polarity event lying between PBG and PBH. This could be the transition from the lower Gauss into the Mammoth event, the transition into the base of the Kaena, the transition out of the top of the Cochiti or the transition out of the top of the Nunivak. Without additional sampling or radiometric dating, this ambiguity cannot be resolved. The underlying three flows, PBC, PBB and PBA give normal directions, if somewhat shallow. Despite the shallow nature, the distribution of directions at PBA at least is very tight. Stratigraphically and petrochemically, site PBX belongs with map unit 5b and the sequence of basalts above, but is reversed. This site has no clear endpoint[1] but neither does it display random behavior to AF demagnetization. It is tentatively assigned to the top of the Gilbert (Epoch 4) implying that the base of map unit 5b samples the Gilbert to Gauss transition at 3.40MY (Mankinen and Dalrymple, 1979). The reason that this second interpretation is not favored is that the overlying sequence of seven flows would all have to fit into the 40,000 year normal interval between the Mammoth and the Kaena. These possibilities could be further assessed with

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[1] On AF demagnetization as the softer (and usually random) components of remanence are progressively removed, the remanence direction changes systematically approaching the true TRM. Once the TRM has been reached, further demagnetization produces no change in direction until all of the remanence has been removed. Sister specimens and other cores from the same site also approach this common TRM direction, which is termed the endpoint.

another stratigraphic section. There is unsampled
stratigraphy adjacent to PBX but it would have to be picked
up laterally (westwards) along the northern Kakuchuya valley
wall. The problem in the vicinity of the PB section is the
morainal cover at this stratigraphic interval where the
hanging valley enters the Kakuchuya.

The underlying map unit 5a is the basal unit of the
stratocone. Sites PBU and PBV (phonolites) and site PBW
(comendite) are all normal. This fact, and the foregoing
discussion, would place the three flows in one of the
short-lived normal events of the Gilbert reversed epoch.
Another pitchstone fission track date of 4.51 ±0.26MY was
obtained from this unit 5a further to the south across the
Kakuchuya-Dudidontu ridge (N. Briggs, pers. comm.). Assuming
this date to correspond to PBW, this site (within error)
could correspond to the Sidufjall normal event between 4.47
and 4.32MY (Mankinen and Dalrymple, 1979), or possibly the
underlying Thvera. One other possibility is that the
sequence of sites is not quite as old as unit 5a laterally,
and that those flows of the PB section are younger than the
date given, possibly placing them during either the Nunivak
or the Cochiti event.

In summary, for the stratocone section, stratigraphic
and map unit divisions correspond fairly well to magnetic
breaks. There are many possible correlations between the PB
section and the geomagnetic polarity time scale. The favored
interpretation is that this sequence of twenty-five lavas

spans most of the recent four geomagnetic polarity epochs,
commencing during the Gilbert at about 4.5MY and continuing
up into the Brunhes, younger than 0.73MY. Alternatively,
assuming that all of the normal and reversed polarity zones
in the lower part of the stratocone have been sampled
results in a minimum age estimate for the base of the
stratocone between 3.40 and 3.15MY. In the favored
interpretation, this sequence catches: the Gauss/Matuyama
transition, the beginning of the transition into the Kaena
or Mammoth event, and the transition from the Gilbert into
the base of the Gauss. Eruptive activity appears to have
been sparse and sporadic because the sampling indicates no
evidence for the various events in the Brunhes and Matuyama
Epochs.

The Plateau Section (PA)-Little Tahltan Canyon

The section of 25 flows sampled from the Little Tahltan
Canyon crosses one of the best exposures of basalts which
comprise the Level Mountain shield. This section is lower
both in elevation and stratigraphic position than the
stratocone section described above.

There is no radiometric data at all for the PA section
and thus any correlation with the standard time-scale must
be regarded as rather tentative. Furthermore, Mankinen and
Dalrymple (1979) do not carry their polarity time scale
beyond about 5MY. Taking the base of the PB section as
representing the Sidufjall event, and simply matching the
sequence of normal and reversed intervals determined by

McDougall et al (1977),see figure 11-3, leads to the conclusion that the lowest sites (PAX and PAY) fall near the middle of Epoch 6 (about 6MY). This is a minimum estimate for the onset of volcanism in the area. If "events" within the Gilbert epoch or Epochs 5 and 6 have been missed in this sampling, which seems probable, the base of the section will be correspondingly older. In this context it is reasonable to suppose that the eight flows (PAE to PAL) represent the lower part of Epoch 5 (5.50-5.83MY), not the very short normal interval at the top of Epoch 5 (5.34-5.37MY) which one-to-one matching implies. It also seems probable that the extremely short events at 6.12 and 6.39MY would not be recorded at Level Mountain. If this is so then sites PAQ to PAS may represent the normal interval 6.27 to 6.39MY, with sites PAX and PAY consequently having an age of about 6.6MY.

The frequency of volcanism during the plateau building is apparently greater than during the subsequent stratocone stage. For the minimum estimate of the onset of volcanism in the area of about 6MY, the duration of plateau building is about 1.5MY and possibly as long as 2.1MY for the case of missed events. This translates to an average time interval between eruptions of sixty to eighty thousand years, or about one order of magnitude more frequent activity than during the stratocone stage. However both the field relations and the remanence vectors indicate that eruptive activity during plateau time was more clustered. From this viewpoint, the four plateau units may have been short lived

intense periods of activity separated by quiescent periods
of about half a million years in duration. For this second
interpretation the quiescent periods during the plateau and
stratocone stages are of about the same length, but the
volumes of erupted material are more than an order of
magnitude different.

A Comparison of the Paleomagnetic Sections from Level Mountain and Mount Edziza

Magnetograms for the three paleomagnetic sections from
Mount Edziza (Souther and Symons, 1974) are shown in Figure
11-4. Tentative correlations of Level Mountain and Mount
Edziza eruptive sequences to the geomagnetic polarity-time
scale are given in Figure 11-5. The directions for sites
PBS, PBR and PBQ agree with the uppermost flows of
stratigraphic sections A and C on Edziza. The uppermost
flows at both centres are basaltic in nature.

Sites PBP, PBO (map unit 8) and PBN (map unit 7) have
steeper inclinations and more westerly declinations than
most of the sites from map units 5, 7 and 9 of Edziza which
are also interpreted to be of Matuyama age. While Souther
and Symons (1974) have apparently caught the Jaramillo
normal event at their site A6, no similar intervening normal
event has been sampled at Level Mountain.

The directions for sites PBP, PBO and PBN are
tentatively likened to the direction at Edziza's site A5
which is placed below the Jaramillo, while the intermediate
chemistry of flows PBP and PBO (benmoreites) is similar to

Figure 11-4.

Magnetograms for the three Edziza stratigraphic sections.
Data from Souther and Symons (1974). Elevation referenced to
base of each section. Bar scale indicates map unit
designation. Connecting lines are broken for time hiatus (or
sampling gap) as inferred from stratigraphic notes.
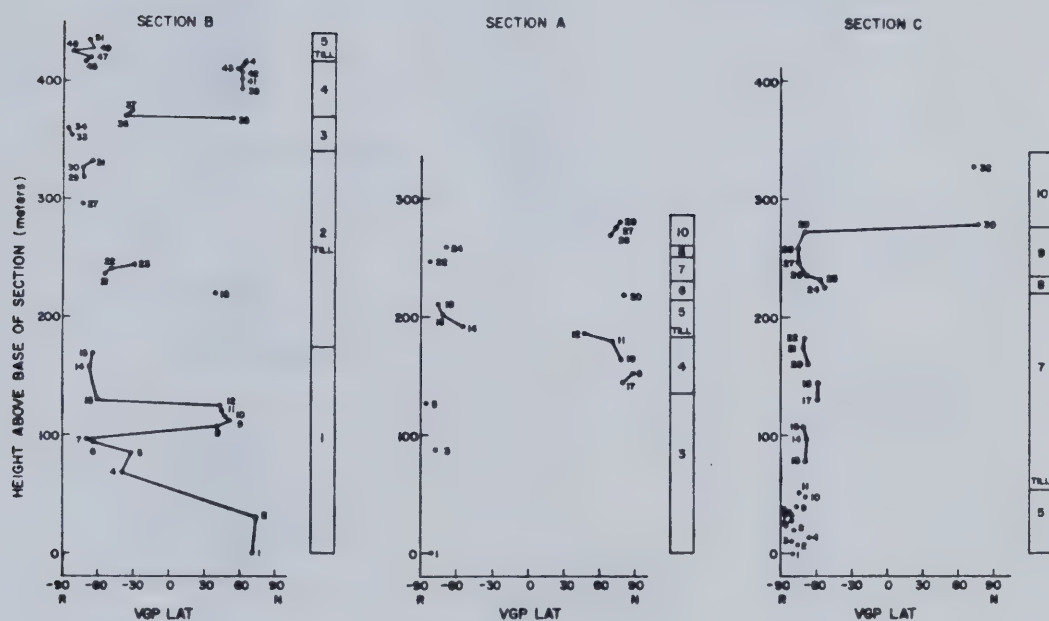
Figure 11-5.
Suggested correlation for volcanism at Level Mountain and
Mount Edziza with the reference polarity time scale.
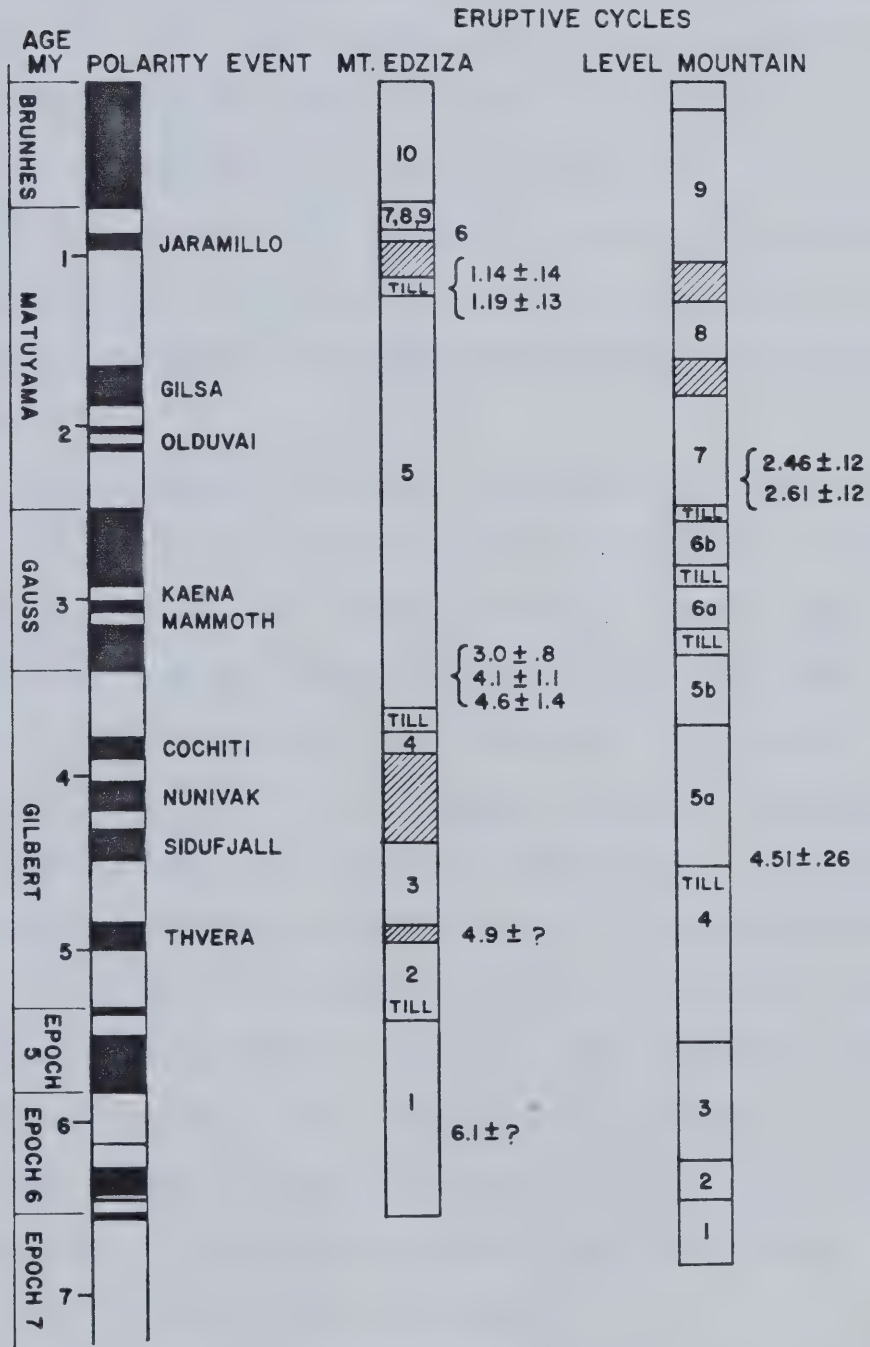
trachybasalts of unit 7 in sections A and C at Edziza.

The eruptive activity of map unit 6 (Level Mountain) appears to have been contemporaneous with glacial activity, as it is underlain by and includes tills, and is overlain by fluvioglacial sands and gravels. While the overlying unit could be Pleistocene, the underlying till implies a glaciation in the region at or prior to 2.5MY. The combination of information on glaciation at Level Mountain and Mount Edziza indicates that 3 or more episodes of continental galciation occurred between the Pleistocene and about 5MY.

The stratigraphic interval including map units 5 and 6 at Level Mountain is lithologically most similar to the sequence from B16 to B32 (Edziza unit 2). These sections are both characterized by abundant peralkaline flows and tuffs. It appears that the bimodal volcanism and stratocone stage at Edziza may preceed its equivalent at Level Mountain by as much as 0.5MY, with such activity beginning at Edziza during the reversed magnetozone of Epoch 5 or at the base of the Gilbert. It is also interesting to note that salic volcanics are included in the Edziza plateau, while at Level Mountain they are restricted to the Stratocone cap. There is a general age, magnetic and lithologic similarity for the stratocone section at Level Mountain and the younger portions of the 3 sections on Edziza.

The lower plateau section (B) at Edziza is bracketed by K-Ar dates as having been erupted between 6.1 and 4.9MY

(Souther and Symons, 1974). The best estimate from combined paleomagnetic and radiometric information is that the Edziza plateau building commences sometime during the lowest normal event of Epoch 6 sampling all three polarity zones of that epoch and the overlying reversed magnetozone of Epoch 5. The low latitude VGP site (PAW) could possibly represent a transition to the short normal zone at the top of Epoch 7. This indicates the possibility that the lowest sampled stratigraphy at Level Mountain is older by at least 0.4MY than the age cited for the base of the Edziza plateau.

CHAPTER 12. SUMMARY AND CONCLUSIONS REGARDING THE PETROGENESIS OF THE LEVEL MOUNTAIN VOLCANICS AND THEIR RELATIONSHIP TO THE TECTONICS OF THE INTERMONTANE BELT.

The most salient geological feature of the Stikine region of northwestern British Columbia is the Late Cenozoic volcanic activity. Since upper Miocene time more than 1700km³ of lavas have been erupted both as isolated flows and major volcanic edifices covering about 12% of the land area in the Stikine Volcanic Belt (Souther,1977b). Within this region are eleven major volcanic centres of which Level Mountain and Mount Edziza are the largest. Most of the Stikine lavas belong to the sodic alkali basalt series and are of continental affinity. At level Mountain there are two volumetrically dominant lava types. Alkali basalt flows and related basic lavas (sub-alkaline basalt, hawaiite, ankaramite) comprise an oval shield approximately 50km in diameter with an average thickness of 600m. The shield-building stage lasted 2MY or more, ending during the Pliocene at about 4.5MY ago. At that time a fundamental change occurred both in the chemistry of the erupted lavas and their physiographic expression. This second stage of volcanism at level Mountain, with much greater variability in the eruptive style (including flows, pyroclastics, domes, cupolas, dykes and hypabyssal stocks), resulted in the construction of a complex centrally-placed stratocone cap approximately 25km in diameter with a thickness of about 750m. While the entire classic sodic alkali basalt

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differentiation series is present, the dominant lavas of the stratocone stage were peralkaline trachytes. Other compositions in decreasing order of abundance are: comendites, rhyolites, hawaiites, benmoreites, phonolites and mugearites.

A variety of models for magma transport were calculated using one-atmosphere viscosity and liquidus determinations for the range of lava compositions. Basic magmas had very rapid ascent velocities in the range of 1 to 10cm/sec with salic magmas being about two orders of magnitude slower. The volumes of typical flows and other single eruption features were on the order of 10^{-1} to $10^{-2} km^3$. That the Level Mountain range is comprised of many such low volume and low viscosity flows argues for low overall rates of volcanicity and the relatively efficient transport of small aliquots of magma directly from the upper mantle.

The isotopic and chemical evidence for the origin of the Level Mountain volcanics is straightforward. Basalts and inclusions with primitive $^{87}Sr/^{86}Sr$ values (0.7025 to 0.70440) and primitive Pb isotope ratios (in the range of typical values for MORB and oceanic islands) argue for an upper mantle derivation from a heterogeneous source. Oxygen isotope values for basalts and inclusions (5.5 to $5.9^o/_o \delta^{18}O$ SMOW) confirm that the upper mantle beneath Level Mountain is normal with respect to oxygen. The shift to lighter isotopic compositions for the stratocone basalts, with respect to those on the shield stage,

indicates some heterogeneity for oxygen in the source region as well, and may indicate a shift in the depth of the melting zone as volcanism proceeded. Considering all of the Late Cenozoic lavas from the IMB, scatter in the O and Sr isotope signatures, along with the variation in major and trace element ratios for lavas of similar evolution, argues for a very local scale heterogeneity in their upper mantle source regions. Somewhat lower abundances of K, Rb, U, Th and light rare earths for lavas of the IMB, compared to those from the source regions of alkalic magmas in general (White et al, 1979), may indicate that the upper mantle beneath the Cordillera has been depleted by prior melting events. Such depletion might have occurred through volcanism and plutonism accompanying the Mesozoic emplacement of allochthonous Cordilleran terranes (Monger and Price, 1979).

The major and trace element chemical variations for all of the Level Mountain lavas are inconsistent with the derivation of the volumetrically important peralkaline lavas of the Stratocone stage via the classical fractional crystallization processes from an alkali basalt primary magma. All of the chemical variation is typified by two clusters which are interpreted to indicate that there are two principle magma types, basalt and peralkaline trachyte. The peralkaline salic magmas have some equally primitive lead, strontium and oxygen isotope values to the basalts, but the range in oxygen and strontium extends to higher values indicating a combination of secondary processes

including crustal contamination and selective open system behavior. The peralkaline salic magmas are traditionally interpreted to be derived by substantial fractional crystallization of a wollastonite-normative intermediate or basaltic parent (the orthoclase effect of Bailey and Schairer, 1966). At Level Mountain the major element variation of these peralkaline lavas (principally Na and K) is inconsistent with a derivation via any extensive alkali feldspar fractionation. This interpretation is also born out in the normalized rare earth patterns which are totally lacking in europium anomalies. The distribution of salic lavas about the thermal minimum in the liquidus surface indicates that they may be a related series of partial melts. Geobarometry estimates for trachytes using silica activities give equilibration depths below 20km, in the lower crust. It is uncertain whether this reflects a depth of origin or rest point on the ascent path for the salic magmas. The high one-atmosphere temperatures determined in this study and the expected shape of the liquidus with increasing pressure (Bailey et al, 1974) suggest that the melting probably does not occur within the crust.

The source compositions and P, T conditions for the origin of the basaltic and peralkaline magmas are not very well constrained. Geothermometry and geobarometry calculations on lherzolite inclusions from the Stikine Volcanic Belt indicate equilibration depths in the range from 30 to 70 kilometers. Geobarometry estimates from silica

and alumina activities on Level Mountain lavas gives a similar depth range. This agrees with data for central B. C. reported by Fiesinger and Nicholls (1977) and Fujii et al, 1981. According to the recent synthesis of P and S wave residuals for the Cordillera, the upper mantle lacks a seismically resolvable high velocity lid, and these aforementionned depth estimates correspond to a range from the base of the crust down through the upper half of the low velocity zone (Wickens and Buchbinder, 1980). While the geobarometry estimates place the likely source region in the stability field for spinel lherzolite, the lherzolite compositions from the IMB are too geochemically depleted (Tatsumoto, 1978) to give rise to extractable quantities of basaltic partial melts. Matrix calculations give maximum partial melts of 4% but less than 1% is far more common. Similar calculations using Level Mountain basalts and a pyrolite source give partial melts in the range from 5% to 10% which is high enough for melt extraction. The salic lavas require either a more enriched source or a different derivation mechanism. Peralkaline partial melts can only be derived from peralkaline bulk compositions, which is an unlikely situation in the crust or the mantle. One possibility is that the upper mantle or portions of it become metasomatized by such processes as gaseous transfer of incompatible elements from deeper in the mantle or by a series of partial melting episodes with inefficient melt extraction (Boettcher and O'Neil, 1980). This differentiated

upper mantle could contain pods of compositions approaching granulite and gabbro, which is what the partial melting calculations for deriving salic melts require.

The cause of the Level Mountain and related Late Cenozoic volcanics of the IMB is an open question. Alkaline magmas are associated with extensional tectonics such as continental rift and oceanic fracture zones but they also occur on oceanic islands, seamount chains and in continental margin environments (MacDonald, 1974; Bailey, 1977). Some of the structural characteristics of the IMB, as deduced from regional geophysics, resemble a continental rift setting. This structural similarity and the presence of alkaline volcanism, led Souther (1977b) to hypothesize an incipient continental rift. A drawback to this model is the lack of active seismicity in the IMB (Milne et al, 1978) and that the magnitude and rates of volcanism for the SVB are lower than East Africa by two orders of magnitude. The related alkaline volcanism of the Anahim Volcanic Belt led Bevier et al (1979) to point out a possible association with a tear fault in the subducted Juan de Fuca plate. There has been no subduction activity in the vicinity of the northern Canadian Pacific margin since approximately 20MY ago (Grow and Atwater, 1970). This lack of a clear cut tectonic association led to a critical assessment the energy requirements for Level Mountain and the Stikine. Calculations on the amount of energy dissipated by volcanism indicate that the Late Cenozoic volcanism of the SVB could

be initiated and maintained by small changes (15%) in the total heat flux for the region. Changes of this magnitude could arise from the small tectonic stresses associated with the modern shear geometry of the adjacent continental margin (slip on the Queen Charlotte fault is about 6cm/yr) or from the re-equilibration of the thermal structure for the underlying upper mantle, with uplift and rebound of the geotherm following the completion of the subduction for the Kula plate in Mid-Tertiary time.

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APPENDIX 1. FIELD AND REMANENCE NOTES ON LEVEL MOUNTAIN STRATOCONE SECTION

SITE   COMMENTS (PB section decreases in elevation to south)

PBT Hawaiite summit of Meszah Peak, map unit 9. Magnetic declination very erratic in site vicinity, possibility of lightening strikes, directions approach selected at different rates from different directions, inhomogeneous magnetization between cores, sister specimens often disagree until cleaned to >800 oersteds. The chosen direction is not a stable endpoint for all cores. The rejected ones were still coming in. Cores 2 through 5 topographically oriented on Nuttlitude cone.

PBS Hawaiite next to highest flow on west shoulder of Meszah Peak between crater and dyke, map unit 9. While three cores approach a common endpoint, cores 4 and 5 do not, indicating the site to be inhomogeneously magnetized.

PBR Hawaiite highest prominent cliff outcrop on West shoulder of Meszah Peak as seen from south side, map unit 9. Abundant xenoliths, all cores approach a common endpoint in 200 to 400 oersted range. Restricting choice to cores 1,2 and 5 at 400 oersteds would improve statistics without changing direction.

PBQ Hawaiite cliff former below PBR map unit 9, abundant xenoliths, all cores approach common endpoint at 200 to 400 oersteds. Restricting choice to cores 1,2 and 5 improves statistics without changing direction. Below this elevation steep slopes, talus and scoria limit available outcrop. Additional section between Q and P could be collected on East face of Meszah Peak with aid of rope work.

PBP Benmoreite map unit 8. Narrow outcrop <3m wide in creek-snow chute on South face of Meszah Peak. Flows at this level are all thin and aside from a few blocky outcrops like this are scoriaceous, many thin trachytes interspersed, frequency decreasing upsection. All cores approach a common endpoint and stay there between 25 and 400 oersteds.

Appendix 1. continued.

PBO Benmoreite map unit 8, lowest blocky outcrop in snow
    chute, abundant mafic inclusions, below this point talus
    and scree cover resumes, all cores are stable at a
    common endpoint from NRM to 800 oersteds. Restricting
    choice to cores 1,2 and 3 improves statistics without
    changing direction.

PBN Trachyte lava tube low on south face of Meszah Peak, map
    unit 7A. All specimens are stable and coincident from
    NRM to 400 oersteds.

PBM Trachyte ledge, unit 7A at break in slope between lava
    tubes and tarn, all cores coincident from NRM to 400
    oersteds.

PBL Trachyte ledge unit 7A. Site inhomogeneously magnetized
    probably due to low and variable magnetic mineral
    content. Cores come in from different directions at
    different rates. Endpoint somewhat scattered. statistics
    can be improved without affecting direction by
    restricting choice to cores 1,2,3 and 4 at 400 oersteds.

PBY Trachyte flow massive columnar jointing, flow 46m thick,
    unit 7A, cores sampled from separate columns 2/3 of the
    way up the flow, site is transitional and scattered. No
    obvious stable endpoint is achieved. Intensity is low
    and remnance is soft. Statistics can't be much improved
    unless sample is dropped to 2 cores.

PBK Basal trachyte flow of unit 7A, near base of cliff
    outcrop formed by PBY. Laterally unit 6 is overlain by
    fluvioglacial/volcanofluvioglacial sands and gravels.
    Site is scattered and transitional. Some of scatter
    could be due to poor coring as all specimens were either
    in three pieces, short, or hole oriented.

PBJ Basalt, unit 6B. Columnar jointed outcrop forms
    waterfall, good agreement of all specimens from NRM to
    400 oersteds.

PBI Hawaiite, unit 6B. Weathering light grey very abundant
    phenocrysts of plagioclase and black augite, good
    agreement of all specimens from NRM to 400 oersteds.

PBH Hawaiite, unit 6B, with very abundant plagioclase and
    black augite. Direction chosen as stable endpoint,
    statistics can be markedly improved without changing
    direction by eliminating core 3, which comes in more
    slowly than the others and shows some disagreement
    between sister specimens, possible hematite and CRM
    component in core 3.

Appendix 1. continued.

PBG Peralkaline trachyte, unit 6A. Uppermost of three
    similar flows, all cores agree with good statistics but
    inclination is very shallow, transitional site.

PBF Peralkaline trachyte, unit 6A. Forms ledge and holds up
    flat profile in stream valley, phenocrysts of
    anorthoclase,fayalite and green pyroxene, all specimens
    agree from NRM to 800 oersteds with shallow inclination,
    transitional direction.

PBE Peralkaline trachyte flow, unit 6A. Holds up prominent
    waterfall, peculiar exfoliation textures, good agreement
    of all specimens but shallow inclination, transitional
    direction. From this point down only the prominent
    resistant flows are sampled, tuffs and agglomerates are
    omitted. Laterally in several places a till is present
    at this stratigraphic level.

PBD Vesicular browm weathered hawaiite, unit 5B, with
    plagioclase and augite phenocrysts. All specimens
    coincide at a shallow inclination transitional
    direction. These cores all contain appreciable maghemite
    both as phenocryst alteration and as veins and
    amygdules.

PBC Amygdaloidal alkali basalt flow, unit 5B. All cores
    achieve stable endpoints but site is somewhat scattered.
    Statistics can be improved without affecting direction
    by eliminating core 3 which was hole oriented.

PBB Alkali basalt with plagioclas and black pyroxene
    phenocrysts, unit 5B. Site somewhat scattered. Core 2
    was eliminated due to inhomogeneity inferred from
    disagreement between sister specimens.

PBA Hawaiite flow, unit 5B, stable endpoint for four
    specimens

PBX Hawaiite rubbly outcrop west of stream cut, unit 5B. No
    exposure in creek at this point due to lateral moraine
    of Kakuchuya valley, site is definitely reversed.
    Eliminating core 2 improves statistics but does not
    affect direction.

PBU Phonolite flows cooled as a single unit. Slight primary
    (?) dip down 11° to N230°E, unit 5A, site is somewhat
    scattered.

Appendix 1. continued

PBV Phonolite flows, unit 5A. Weak site, all specimens but
    one have common NRM direction but scatter away randomly
    by 100 oersteds indicating a soft remnance.

PBW Crystalline comendite flow, unit 5A. Stable direction
    for all cores from NRM to 100 oersteds.

APPENDIX 2. FIELD AND REMANENCE NOTES ON LEVEL MOUNTAIN PLATEAU SECTION

SITE   COMMENTS (Little Tahltan section decreases in elevation to south along E facing cliff)

PAA Alkali basalt flow, map unit 4. Columnar outcrop, local topographic high back from cliff edge, possible lightening strikes, inhomogeneous site all cores approach the chosen endpoint but at different rates. Cores 3 and 5 were rejected as they were still coming in at 400 oersteds but became random by 600.

PAB Alkali basalt flow, map unit 4, 3m thick columnar flow sampled 1m up from base. This was the next prominent outcrop 150m south of PAA, very coherent site, stable from NRM to 400 oersteds.

PAC Hawaiite flow, map unit 4, abundant phenocrysts of plagioclase and black clinopyroxene, good site, all cores agree from NRM to 200 oersteds.

PAD Alkali basalt, map unit 4. Site is reversed but scattered, while individual cores attain stable endpoints (1 and 4), there is no common direction. Each core came from a different column and the flow was sampled over a distance of 15m laterally but this is not atypical.

PAE Hawaiite map unit 4, very tight site. All cores agree from NRM to 400 oersteds.

PAF Hawaiite, map unit 4. No safe acess at this point in section so PAF was sampled 300m line of site to the south, good endpoint for all cores 100 to 200 oersteds.

PAG Hawaiite, map unit 4. Good endpoint. All specimens stable and coincident from 50 to 400 oersteds.

PAH Hawaiite basal columnar flow of map unit 4 rests on yellowish green tuff horizon that delimits units 3 and 4 over much of the southern plateau, stable direction, all cores agree from NRM to 200 oersteds.

PAI Basalt highest major cooling unit of continous exposure and thickness of unit 3, spheriodially weathering coarse ophitic texture. The five cores here were sampled from only two columns, good site, all cores agree in 100 to 200 oersted range.

APPENDIX 2. continued.

PAJ Alkali basalt, map unit 3, good site, all specimens
agree in 100 to 200 oersted range.

PAK Alkali basalt, map unit 3, calcite and zeolites present,
rejecting core 5 improves statistics without
significantly changing direction.

PAL Alkali basalt, basal flow of 3 that comprises a single
columnar cooling unit, forms promontory north of stream
notch in cliff. While the overlying section was sampled
along 2km of cliff margin, the underlying section
follows the stream notch in this cliff and is nearly
vertical. All cores for this suite attain a good common
endpoint between 100 and 200 oersteds.

PAM Basalt flow with thompsonite and chabazite in fractures.
This is third flow down from PAL due to poor acess, map
unit 3. The intervening flows may contain the transition
from the reverse polarity of PAL. The stable endpoint is
achieved by all cores at 200 oersteds, the direction is
a little shallow making this a transitional site.

PAN Alkali basalt unit 3, lower flow of pair that comprises
a single columnar cooling unit immediately below PAM,
site somewhat scattered similar shallow reversed
direction to PAM, statistics can be improved by
restricting choice to cores 2,3 and 5 but direction does
not change.

PAO Basalt unit 3, xenocrysts of forsterite and brown
spinel, , good site tight distribution for 25 to 400
oersteds on all but core 4, which is consequently
rejected.

PAP Basalt columnar outcrop, unit 3, overlies carbonized
wood and peat, site reversed and somewhat scattered best
agreement in direction at 200 oersteds but core 4 still
coming in.

PAQ Alkali basalt, lowest flow in unit 3, upwards to PAP
there are two flows and a rubbly Lahar which were not
sampled due to poor access on cliff face, this sampling
gap coincides with a polarity change, this site is
normal with good agreement for all cores above 200
oersteds despite the fact that PAQ is mapped in unit 3
and seems to belong there chemically as well, its
magnetic orientation appears to go better with
underlying PAR and PAS. The time interval between units
2 and 3 is probably small.

APPENDIX 2. continued

PAR Alkali basalt separated from PAQ by an orange-buff tuff
    horizon mapped as the unit 2-3 boundary. There is good
    agreement for all cores by 200 oersteds except #2 which
    did not have a sun bearing and the two topographic
    sitings disagreed. This core also did not achieve an
    endpoint so it should be rejected.

PAS Transitional hawaiite-basalt map unit 2, Two flows
    between here and PAR were omitted due to cover inside
    the notch and no access on the cliff face, core 5 had to
    be rejected because it disagreed with all other cores
    and was more intensely magnetized by 2 to 3 orders of
    magnitude, otherwise this is a good site.

PAT Vesicular altered hawaiite (?) flow map unit 2, two
    flows omitted between here and PAS. From here down cliff
    exposure required that safety ropes be used during
    drilling and orientation. This site is quite scattered,
    all cores achieve endpoints but only 1 and 2 coincide,
    the site is reversed but probably has a later CRM
    component related to maghematite alteration as seen
    petrographically, and in failure of core to saturate
    even by 5 kilogauss in IRM test.

PAU Basalt, map unit 2, massive columnar flow >5m thick, one
    flow between here and PAT not sampled, most cores
    coincide from NRM to 400 oersteds.

PAV Basalt lowest massive flow in map unit 2. This columnar
    cooling unit is comprised of four individual flows, one
    cooling unit between here and PAU not sampled. Cores 2
    and 3 were drilled through fractures and became broken
    in several pieces and had to be hole oriented. They
    scatter somewhat from other 3 cores which show good
    agreement by 200 oersteds.

PAW Alkali basalt highest cooling unit in map unit 1, the 1
    to 2 boundary, mapped at the top of PAW because of
    distinctive colour and massive appearance of underlying
    flows. However there is no tuff horizon, paleosol or
    other obvious time break here. This site has an unusual
    shallow inclination but is normal compared to adjacent
    flows above and below. It is also low intensity for
    basalts, probably represents an excursion since long
    time break is not inferred.

APPENDIX 2. continued.

PAX Transitional basalt massive cooling unit typical of map
    unit 1, good agreement for all cores from NRM to 200
    oersteds.

PAY Basalt massive basal flow of map unit 1. Below this
    level there is no further outcrop nearby, only several
    hundred feet of rubbly cold agglomerates
    (volcano-fluviatile). The Little Tahltan River here
    appears to be resequent to a Tertiary stream valley of
    moderate proportions. Bedrock is porphyry similar to
    outcrop on Kaketsa Mtn. and of the Sloko volcanics.
    Although all cores agree with high Fisher k the best
    direction is probably given by cores 1 and 4 at 100 to
    400 oersteds as other cores approach and pass through
    this region.

APPENDIX 3. REMANENCE DATA FOR LEVEL MOUNTAIN LAVAS

SITE	DENS	ELEV	TREAT	EMU	INC	DEC
PBT01A	3.1	7250	0	3.52E-03	62.6	-5.1
PBT01A	3.1	7250	25	3.08E-03	61.6	-17.0
PBT01A	3.1	7250	50	2.40E-03	59.1	-1.9
PBT01A	3.1	7250	100	1.04E-03	56.2	8.4
PBT01A	3.1	7250	200	9.92E-03	69.1	19.1
PBT01A	3.1	7250	400	8.06E-03	50.0	42.4
PBT01A	3.1	7250	800	2.77E-03	60.0	50.0
PBT01A	3.1	7250	1000	2.27E-03	62.1	51.6
PBT02B	2.9	7250	0	4.46E-03	196.5	13.4
PBT02B	2.9	7250	25	4.39E-03	197.5	14.7
PBT02B	2.9	7250	50	3.89E-03	202.1	20.1
PBT02B	2.9	7250	100	2.76E-03	196.0	63.1
PBT02B	2.9	7250	200	1.16E-03	59.7	86.8
PBT02B	2.9	7250	400	5.06E-04	3.0	84.1
PBT02B	2.9	7250	800	1.59E-04	70.0	44.5
PBT03A	3.0	7250	0	4.09E-03	331.9	55.5
PBT03A	3.0	7250	25	4.09E-03	333.9	57.2
PBT03A	3.0	7250	50	4.35E-03	333.9	56.9
PBT03A	3.0	7250	100	3.23E-03	357.0	58.9
PBT03A	3.0	7250	200	1.55E-03	9.8	73.7
PBT03A	3.0	7250	400	4.53E-04	19.4	77.8
PBT03C	3.0	7250	800	3.53E-03	334.9	55.7
PBT03C	3.0	7250	0	3.53E-03	334.8	55.8
PBT03C	3.0	7250	25	3.52E-03	325.1	65.1
PBT03C	3.0	7250	50	3.53E-03	334.9	55.7
PBT03C	3.0	7250	100	2.47E-03	19.1	63.6
PBT03C	3.0	7250	200	1.51E-03	34.9	65.9
PBT03C	3.0	7250	400	4.59E-06	68.6	64.2
PBT03T	3.0	7250	800	3.55E-04	42.8	87.1
PBT03T	3.1	7250	0	2.41E-04	63.7	83.6
PBT03T	3.1	7250	25	9.81E-05	63.5	78.7
PBT03T	3.1	7250	50	3.36E-05	53.1	74.6
PBT03T	3.1	7250	100	1.51E-05	44.8	73.3
PBT03T	3.1	7250	200	4.59E-06	44.0	76.6
PBT03T	3.1	7250	400	1.62E-06	72.6	76.7
PBT04B	3.1	7250	700	1.87E-03	253.9	61.5
PBT04B	2.4	7250	1000	1.82E-03	255.2	56.3
PBT04B	2.4	7250	0	1.66E-03	260.2	20.5
PBT04B	2.4	7250	25	1.05E-03	248.8	31.3
PBT04B	2.4	7250	50	1.59E-03	274.5	71.0
PBT04B	2.4	7250	100	4.55E-03	223.1	71.0
PBT04B	2.4	7250	200	3.38E-03	276.0	68.2
PBT05B	2.4	7250	800	2.50E-03	72.9	40.9
PBT05B	2.9	7250	1000	1.57E-01	11.6	83.0
PBT05B	2.9	7250	200	1.36E-02		

SITE	DENS	ELEV	TREAT	EMU	INC	DEC
PBT05B	2.9	7250	400	4.95E-03	36.9	78.4
PBT05B	2.9	7250	800	1.97E-03	43.3	68.4
PBT05B	2.9	7250	1000	1.29E-03	40.5	72.3
PBS01C	3.0	7200	0	9.48E-03	11.8	51.7
PBS01C	3.0	7200	100	5.16E-03	22.0	49.9
PBS01C	3.0	7200	200	1.92E-03	21.0	52.6
PBS01C	3.0	7200	400	5.58E-04	15.6	56.5
PBS01C	3.0	7200	800	1.84E-04	50.0	57.0
PBS02A	2.9	7200	0	1.06E-02	54.5	8.6
PBS02A	2.9	7200	100	5.53E-03	22.9	26.8
PBS02A	2.9	7200	200	1.94E-03	25.5	35.7
PBS02A	2.9	7200	400	7.67E-04	33.6	41.7
PBS02A	2.9	7200	800	2.62E-04	40.3	50.8
PBS03C	3.0	7200	0	1.26E-02	52.1	-18.8
PBS03C	3.0	7200	25	1.13E-02	43.2	-10.1
PBS03C	3.0	7200	50	8.79E-03	32.5	2.1
PBS03C	3.0	7200	100	5.19E-03	26.0	14.2
PBS03C	3.0	7200	200	1.42E-03	24.9	26.8
PBS03C	3.0	7200	400	5.66E-04	21.6	35.2
PBS03C	3.0	7200	800	1.76E-04	47.3	57.4
PBS04A	2.9	7200	0	2.55E-01	354.4	6.2
PBS04A	2.9	7200	100	5.54E-02	7.6	17.9
PBS04A	2.9	7200	200	5.29E-03	8.1	11.3
PBS04A	2.9	7200	400	1.22E-03	6.7	4.4
PBS05B	3.0	7200	0	4.12E-01	58.6	-7.1
PBS05B	3.0	7200	100	8.98E-02	50.2	-9.9
PBS05B	3.0	7200	200	2.19E-02	51.4	-8.7
PBR01B	3.0	7200	400	1.00E-02	51.7	-5.9
PBR01B	3.0	6625	0	8.73E-03	130.0	62.8
PBR01B	3.0	6625	100	3.16E-03	50.6	63.7
PBR01B	3.0	6625	200	1.12E-03	51.8	60.8
PBR02B	3.0	6625	400	5.38E-04	37.7	58.7
PBR02B	3.0	6625	800	5.69E-04	22.8	10.4
PBR02B	3.0	6625	0	8.72E-03	41.6	54.1
PBR02B	3.0	6625	100	4.37E-03	41.2	61.3
PBR02B	3.0	6625	200	2.35E-03	29.1	62.5
PBR03B	3.0	6625	800	9.06E-04	28.7	62.3
PBR03B	3.0	6625	100	1.42E-04	18.2	60.2
PBR03B	3.0	6625	200	4.82E-02	105.2	21.5
PBR03B	3.0	6625	400	5.55E-03	80.7	47.0
PBR03B	3.0	6625	800	2.24E-03	69.7	53.8
PBR04B	3.0	6625	0	7.98E-04	73.3	50.8
PBR04B	3.0	6625	100	7.97E-04	71.7	50.7
PBR04B	3.0	6625	200	2.01E-02	112.1	39.2
PBR04B	3.0	6625	800	4.10E-03	68.7	65.1
PBR04B	3.0	6625	100	1.61E-03	70.0	64.5
PBR05B	3.0	6625	200	3.85E-04	99.8	69.6
PBR05B	3.0	6625	800	1.05E-04	134.4	52.2
PBR05B	3.0	6625	100	8.63E-03	32.7	52.9
PBR05B	3.0	6625	200	4.87E-03	34.0	61.2
PBR05B	3.0	6625	400	2.42E-03	35.2	62.4
PBR05B	3.0	6625	800	1.03E-03	35.2	63.5
PBQ01A	3.0	6580	0	2.34E-04	24.2	61.5
PBQ01A	3.0	6580		9.35E-03	39.9	56.1

SITE	DENS	ELEV	TREAT	EMU	INC	DEC
PBQ01A	3.0	6580	100	3.75E-03	26.5	58.8
PBQ01A	3.0	6580	200	1.11E-03	29.4	55.3
PBQ01A	3.0	6580	400	5.14E-04	37.1	55.2
PBQ02B	3.0	6580	0	9.03E-03	35.3	55.2
PBQ02B	3.0	6580	100	3.88E-03	36.3	54.1
PBQ02B	3.0	6580	200	1.21E-03	41.0	54.8
PBQ02B	3.0	6580	400	5.41E-04	38.6	46.8
PBQ03B	3.0	6580	0	2.68E-02	143.8	12.4
PBQ03B	3.0	6580	25	2.09E-02	142.8	13.2
PBQ03B	3.0	6580	50	1.07E-02	135.2	21.9
PBQ03B	3.0	6580	100	3.27E-03	117.3	40.8
PBQ03B	3.0	6580	200	7.79E-04	79.0	61.4
PBQ04B	3.0	6580	400	3.75E-04	54.6	57.5
PBQ04B	2.9	6580	800	1.46E-04	66.7	54.5
PBQ04B	2.9	6580	0	2.67E-02	104.2	17.5
PBQ04B	2.9	6580	100	6.16E-03	89.9	28.6
PBQ04B	2.9	6580	200	1.68E-03	78.6	37.3
PBQ04B	2.9	6580	400	5.84E-04	79.9	38.9
PBQ05B	2.8	6580	800	7.61E-03	68.3	46.1
PBQ05B	2.8	6580	100	1.56E-04	18.6	32.6
PBQ05B	2.8	6580	200	2.79E-03	21.1	48.0
PBQ05B	2.8	6580	400	1.47E-03	21.8	51.3
PBP01B	2.6	6480	0	8.80E-04	21.9	51.5
PBP01B	2.6	6480	100	8.27E-04	224.5	-58.6
PBP01B	2.6	6480	200	9.47E-04	225.3	-66.9
PBP02A	2.6	6480	0	7.18E-04	225.4	-66.4
PBP02A	2.5	6480	100	8.41E-04	146.9	-71.6
PBP02A	2.5	6480	200	9.22E-04	182.0	-76.2
PBP03A	2.5	6480	0	6.79E-04	188.5	-76.0
PBP03A	2.5	6480	100	8.06E-04	242.4	-86.2
PBP04B	2.5	6480	0	9.29E-04	198.0	-76.4
PBP04B	2.5	6480	100	6.76E-04	202.0	-75.8
PBP04B	2.5	6480	200	7.08E-04	295.7	-71.2
PBP04B	2.5	6480	25	9.30E-04	260.7	-79.1
PBP04B	2.5	6480	50	1.01E-03	244.9	-80.8
PBP04B	2.5	6480	100	6.24E-04	220.4	-82.3
PBP04B	2.5	6480	200	3.44E-04	233.8	-79.8
PBP05A	2.5	6480	400	8.55E-04	235.6	-76.0
PBP05A	2.5	6480	100	5.93E-04	343.1	-68.7
PBO01B	2.6	6440	200	2.24E-03	217.7	-68.4
PBO01B	2.6	6440	800	2.33E-03	223.9	-68.2
PBO02C	2.6	6440	100	2.11E-03	202.7	-85.0
PBO02C	2.5	6440	50	1.74E-03	222.0	-85.4
PBO02C	2.5	6440	25	1.73E-03	230.3	-75.6
PBO02C	2.5	6440	50	1.73E-03	228.3	-76.0
PBO02C	2.5	6440	100	1.72E-03	227.7	-77.5
PBO03C	2.5	6440	200	1.76E-04	210.3	-83.4
PBO03C	2.5	6440	400	8.45E-04	174.6	-86.2
PBO03C	2.4	6440	800	8.57E-04	223.3	-79.3
PBO03C	2.4	6440	0	4.52E-03	87.6	-86.4
			100	4.28E-03	50.8	-87.7

SITE	DENS	ELEV	TREAT	EMU	INC	DEC
PBO03C	2.4	6440	200	3.35E-03	45.1	-86.4
PBO04A	2.6	6440	0	1.74E-03	80.4	-73.1
PBO04A	2.6	6440	50	1.80E-03	68.8	-79.3
PBO04A	2.6	6440	100	1.65E-03	63.6	-79.3
PBO05A	2.6	6440	0	1.20E-02	178.3	-76.7
PBO05A	2.6	6440	50	1.18E-02	179.6	-76.3
PBO05A	2.6	6440	100	1.14E-02	180.5	-76.7
PBN01B	2.5	6340	50	1.01E-02	275.9	-79.4
PBN01B	2.5	6340	100	8.95E-03	270.0	-79.6
PBN02A	2.7	6340	200	6.31E-03	260.6	-79.3
PBN02A	2.6	6340	100	1.12E-02	262.2	-78.2
PBN02A	2.7	6340	200	9.91E-03	260.3	-77.9
PBN03C	2.5	6340	100	6.73E-03	257.6	-77.4
PBN03C	2.6	6340	200	1.04E-02	268.5	-77.0
PBN03C	2.5	6340	100	9.20E-03	264.0	-76.8
PBN04A	2.5	6340	200	6.51E-03	260.4	-76.8
PBN04A	2.5	6340	100	1.10E-02	267.7	-77.8
PBN04A	2.5	6340	200	9.91E-03	262.6	-77.6
PBN05A	2.5	6340	100	1.26E-02	280.0	-79.3
PBN05A	2.5	6340	200	7.31E-03	270.8	-80.0
PBM01A	2.6	6160	100	2.21E-03	223.3	-62.3
PBM01A	2.6	6160	200	2.20E-03	222.9	-63.4
PBM02B	2.6	6160	100	2.14E-03	223.0	-63.4
PBM02B	2.6	6160	200	2.03E-03	234.6	-62.8
PBM02B	2.6	6160	100	2.05E-03	235.1	-62.8
PBM02B	2.6	6160	200	2.02E-03	235.3	-62.9
PBM02B	2.6	6160	800	1.86E-03	235.5	-63.0
PBM03A	2.6	6160	100	1.17E-03	229.7	-64.0
PBM03A	2.6	6160	50	1.70E-03	146.7	-56.5
PBM03A	2.6	6160	100	1.68E-03	216.6	-63.3
PBM04A	2.6	6160	0	1.70E-03	218.1	-62.7
PBM04A	2.6	6160	50	1.71E-03	216.1	-62.1
PBM05A	2.6	6160	100	1.72E-03	218.1	-62.2
PBM05A	2.6	6160	200	2.18E-03	216.0	-58.7
PBL01A	2.5	5835	0	2.40E-04	77.7	49.1
PBL01A	2.6	5835	50	1.17E-02	92.0	48.7
PBL01A	2.6	5835	100	4.86E-05	162.4	-15.3
PBL01A	2.7	5835	200	2.39E-05	169.4	-55.5
PBL01A	2.7	5835	400	2.70E-05	114.6	-40.1
PBL02B	2.7	5835	0	1.99E-04	100.9	4.5
PBL02B	2.7	5835	50	1.71E-04	120.6	-36.7
PBL02B	2.7	5835	100	1.41E-04	143.0	-61.7
PBL02B	2.7	5835	200	1.61E-04	151.8	-67.1
PBL02B	2.7	5835	400	4.76E-04	99.1	-59.9
PBL03C	2.6	5835	25	7.04E-05	224.9	59.9
PBL03C	2.6	5835	50	5.38E-05	205.4	39.8
PBL03C	2.6	5835	50	6.33E-05	194.6	-19.8

SITE	DENS	ELEV	TREAT	EMU	INC	DEC
PBL03C	2.6	5835	100	1.38E-04	190.0	-54.8
PBL03C	2.6	5835	200	1.60E-04	189.2	-61.9
PBL03C	2.6	5835	400	1.27E-04	193.6	-65.6
PBL03C	2.6	5835	800	7.06E-05	182.5	-67.2
PBL04A	2.6	5835	0	1.33E-04	148.0	-66.9
PBL04A	2.6	5835	50	1.66E-04	165.6	-67.8
PBL04A	2.6	5835	100	1.75E-04	169.4	-68.7
PBL04A	2.6	5835	200	1.58E-04	166.6	-68.5
PBL05A	2.6	5835	400	1.86E-04	270.0	-69.8
PBL05A	2.6	5835	0	1.87E-04	168.3	-37.5
PBL05A	2.6	5835	50	2.08E-04	171.2	-51.5
PBL05A	2.6	5835	100	2.26E-04	174.1	-58.4
PBL05A	2.6	5835	200	2.64E-04	266.0	-66.5
PBL05A	2.6	5835	400	1.14E-04	180.8	-68.5
PBY01A	2.6	5780	0	5.78E-04	56.5	62.9
PBY01A	2.6	5780	50	2.95E-04	50.6	57.4
PBY01A	2.6	5780	100	8.64E-05	27.9	39.3
PBY01A	2.6	5780	200	2.19E-04	43.9	18.0
PBY01A	2.6	5780	300	6.32E-05	28.4	12.1
PBY02B	2.6	5780	400	2.83E-05	15.2	21.6
PBY02B	2.6	5780	0	5.60E-04	10.1	53.2
PBY02B	2.6	5780	50	2.47E-04	359.9	48.0
PBY02B	2.6	5780	100	1.01E-04	11.1	27.7
PBY02B	2.6	5780	200	3.82E-05	9.6	-3.5
PBY03C	2.6	5780	300	6.13E-05	35.7	19.2
PBY03C	2.6	5780	400	2.58E-05	2.3	12.8
PBY03C	2.6	5780	0	8.94E-04	43.1	75.4
PBY03C	2.6	5780	25	1.74E-04	44.3	75.5
PBY03C	2.6	5780	50	6.51E-05	72.6	61.9
PBY04C	2.6	5780	100	3.89E-05	36.7	12.5
PBY04C	2.6	5780	200	1.40E-05	17.6	10.9
PBY04C	2.6	5780	400	7.11E-04	37.2	-30.1
PBY04C	2.6	5780	0	2.06E-04	22.4	42.6
PBY04C	2.6	5780	25	6.92E-05	104.8	46.9
PBY05B	2.6	5780	50	1.58E-05	106.0	47.2
PBY05B	2.5	5780	100	7.32E-06	30.8	35.5
PBY05B	2.5	5780	200	1.14E-04	14.5	-7.2
PBY05B	2.5	5780	400	3.27E-04	359.9	-20.3
PBK01A	2.5	5745	800	2.54E-04	321.3	-29.1
PBK01A	2.5	5745	50	1.94E-04	358.2	26.8
PBK01A	2.5	5745	100	8.89E-05	355.7	-7.3
PBK01A	2.5	5745	200	3.54E-04	297.4	-16.9
PBK02A	2.5	5745	0	7.25E-05	55.7	61.2
PBK02A	2.5	5745	50	6.53E-05	56.2	50.3
PBK02A	2.5	5745	100	4.68E-04	22.8	41.7
PBK02A	2.5	5745	200	3.38E-04	17.3	22.6
PBK02A	2.5	5745	50	1.78E-04	344.7	73.2
PBK02A	2.5	5745	100	7.52E-05	343.3	47.7

SITE	DENS	ELEV	TREAT	EMU	INC	DEC
PBK02A	2.5	5745	200	4.75E-05	348.5	23.1
PBK02A	2.5	5745	400	1.79E-05	349.1	8.3
PBK02A	2.5	5745	800	3.11E-05	9.0	-6.3
PBK03A	2.6	5745	0	2.12E-04	200.2	85.2
PBK03A	2.6	5745	50	6.10E-05	353.9	21.4
PBK03A	2.6	5745	100	6.60E-05	351.4	-16.9
PBK03A	2.6	5745	200	4.86E-05	5.0	-15.7
PBK04A	2.6	5745	400	2.67E-04	5.2	0.7
PBK04A	2.6	5745	0	3.56E-04	12.2	34.5
PBK04A	2.6	5745	50	2.99E-04	5.4	18.6
PBK04A	2.6	5745	100	2.53E-04	360.0	1.0
PBK04A	2.6	5745	200	2.12E-04	355.5	-10.9
PBK04A	2.6	5745	400	7.98E-05	356.4	-13.9
PBK05A	2.5	5745	0	3.66E-04	4.8	12.5
PBK05A	2.5	5745	50	3.30E-04	8.8	2.1
PBK05A	2.5	5745	100	2.97E-04	10.6	-6.2
PBK05A	2.5	5745	200	2.47E-04	10.1	-15.3
PBJ01A	2.8	5690	400	1.30E-04	10.2	-20.1
PBJ01A	2.8	5690	0	1.97E-03	37.7	77.5
PBJ01A	2.8	5690	50	1.08E-03	22.6	69.8
PBJ02B	2.8	5690	100	6.41E-04	24.2	71.6
PBJ02B	2.8	5690	0	2.24E-03	25.1	66.8
PBJ02B	2.8	5690	50	1.18E-03	33.1	74.0
PBJ03C	2.7	5690	100	6.78E-04	26.6	71.4
PBJ03C	2.7	5690	50	1.91E-04	346.7	71.0
PBJ03C	2.7	5690	100	9.65E-04	297.4	85.9
PBJ04C	2.9	5690	50	5.23E-04	56.7	71.0
PBJ04C	2.9	5690	100	1.53E-03	45.6	73.9
PBJ04C	2.9	5690	25	1.00E-03	55.6	78.3
PBJ04C	2.9	5690	50	8.33E-04	26.9	74.5
PBJ04C	2.9	5690	100	6.05E-04	346.8	81.6
PBJ04C	2.9	5690	200	4.05E-04	25.3	71.1
PBJ05B	2.9	5690	800	1.49E-04	28.2	72.8
PBJ05B	2.8	5690	50	2.65E-04	62.5	35.8
PBI01A	2.8	5690	100	1.00E-03	20.8	69.9
PBI01A	2.8	5675	50	7.46E-04	24.4	69.9
PBI01A	2.8	5675	100	5.05E-03	329.8	79.0
PBI01A	2.8	5675	200	4.54E-03	338.1	80.6
PBI02B	2.8	5675	100	3.54E-03	347.3	79.8
PBI02B	2.9	5675	200	6.89E-03	20.2	77.3
PBI02B	2.9	5675	50	6.58E-03	30.9	78.2
PBI02B	2.9	5675	100	6.15E-03	24.3	78.3
PBI02B	2.9	5675	200	4.79E-03	20.8	79.2
PBI02B	2.9	5675	400	2.09E-03	13.8	80.0
PBI03C	2.9	5675	800	3.44E-04	51.6	81.6
PBI03C	2.8	5675	100	4.90E-03	66.0	66.0
PBI04B	2.8	5675	200	1.63E-03	51.6	66.0
PBI04B	2.8	5675	400	1.02E-02	320.1	84.9
PBI04B	2.8	5675	100	3.32E-03	65.6	77.0
PBI04B	2.8	5675	100	1.75E-03	35.3	81.6
PBI05B	2.8	5675	200	9.39E-03	32.8	80.3
PBI05B	2.7	5675	0	3.85E-03	44.3	63.6

SITE	DENS	ELEV	TREAT	EMU	INC	DEC
PBI05B	2.7	5675	100	1.82E-03	40.3	68.1
PBI05B	2.7	5675	200	1.04E-03	41.7	72.5
PBH01A	2.7	5655	0	3.19E-03	33.7	73.0
PBH01A	2.7	5655	50	2.53E-03	7.3	80.1
PBH01A	2.7	5655	100	2.38E-03	4.3	81.7
PBH01B	2.8	5655	0	2.48E-02	91.2	36.4
PBH01B	2.8	5655	50	1.73E-02	94.0	34.4
PBH01B	2.8	5655	100	7.82E-03	94.3	39.7
PBH01B	2.8	5655	200	2.25E-03	86.8	57.8
PBH01B	2.8	5655	400	6.51E-04	70.2	66.9
PBH02B	2.7	5655	50	4.21E-03	5.8	71.6
PBH02B	2.7	5655	100	2.94E-03	357.6	77.5
PBH02B	2.7	5655	200	1.88E-03	357.8	78.6
PBH03B	2.8	5655	50	2.17E-02	13.6	39.0
PBH03B	2.8	5655	100	3.81E-03	4.6	53.1
PBH03B	2.8	5655	200	1.70E-04	352.5	74.3
PBH03C	2.8	5655	50	5.10E-02	24.9	-45.5
PBH03C	2.8	5655	100	1.35E-02	347.4	19.5
PBH03C	2.8	5655	200	8.28E-04	298.5	30.0
PBH03C	2.8	5655	400	5.36E-02	281.3	26.9
PBH03D	2.8	5655	0	8.34E-02	280.0	-1.0
PBH03D	2.8	5655	25	4.63E-02	281.3	2.3
PBH03D	2.8	5655	50	1.82E-02	276.8	8.0
PBH03D	2.8	5655	100	4.01E-03	273.0	27.1
PBH03D	2.8	5655	200	1.86E-03	275.1	43.6
PBH03D	2.8	5655	400	7.85E-04	276.3	48.0
PBH03D	2.8	5655	800	1.42E-04	306.3	53.0
PBH03D	2.8	5655	1000	1.46E-04	294.6	48.0
PBH03D	2.8	5655	1200	2.88E-05	339.3	0.3
PBH04B	2.8	5655	0	4.17E-03	56.5	72.4
PBH04B	2.8	5655	25	2.39E-03	26.1	82.4
PBH04B	2.7	5655	50	1.51E-03	22.7	81.2
PBH04B	2.7	5655	100	4.46E-03	318.5	75.6
PBH05A	2.7	5655	50	2.76E-03	335.6	80.2
PBH05A	2.7	5655	100	1.91E-03	349.6	80.2
PBG01A	2.5	5580	0	2.83E-04	21.6	3.1
PBG01A	2.5	5580	100	2.71E-04	21.0	1.2
PBG01A	2.5	5580	200	2.41E-04	21.2	0.5
PBG02B	2.5	5580	100	3.19E-04	17.4	0.2
PBG02B	2.5	5580	200	2.97E-04	18.6	-4.1
PBG02B	2.5	5580	400	2.50E-04	18.7	-4.7
PBG03A	2.5	5580	100	2.32E-04	17.8	6.4
PBG03A	2.5	5580	200	2.17E-04	19.3	-1.3
PBG03A	2.5	5580	400	1.77E-04	19.4	-2.7
PBG04A	2.5	5580	50	3.88E-04	27.0	9.8
PBG04A	2.5	5580	100	3.57E-04	23.7	4.7
PBG04A	2.5	5580	200	3.11E-04	23.3	2.8
PBG05C	2.4	5580	100	2.99E-04	14.0	4.6
PBG05C	2.4	5580	50	3.03E-04	13.9	3.0
PBG05C	2.4	5580	100	2.97E-04	13.5	-0.2
PBG05C	2.4	5580	200	2.90E-04	13.5	-1.9
PBG05C	2.4	5580	400	2.36E-04	14.5	-4.0
PBG05C	2.4	5580	800	1.74E-04	14.5	4.0
PBG05C	2.4	5580		1.26E-04	13.2	2.4

SITE	DENS	ELEV	TREAT	EMU	INC	DEC
PBF01A	2.5	5545	0	2.82E-05	28.1	62.8
PBF01A	2.5	5545	100	7.77E-06	20.3	47.9
PBF01A	2.5	5545	200	4.57E-06	0.6	10.9
PBF01A	2.5	5545	400	1.38E-06	43.5	18.1
PBF02C	2.7	5545	25	3.00E-04	11.1	10.2
PBF02C	2.7	5545	50	3.00E-04	11.3	8.9
PBF02C	2.7	5545	100	2.95E-04	10.9	6.2
PBF02C	2.7	5545	200	2.46E-04	10.8	3.8
PBF02C	2.7	5545	400	1.58E-04	9.7	3.0
PBF03A	2.7	5545	800	5.37E-05	10.8	4.3
PBF03A	2.5	5545	100	1.18E-04	10.8	12.6
PBF03A	2.6	5545	200	1.08E-04	18.3	6.2
PBF04B	2.6	5545	100	2.29E-04	16.4	13.3
PBF04B	2.6	5545	200	2.21E-04	17.6	4.0
PBF05B	2.6	5545	100	2.09E-04	11.2	8.6
PBF05B	2.6	5545	200	1.84E-04	13.6	4.4
PBE01C	2.5	5475	100	2.05E-04	22.9	-0.3
PBE01C	2.5	5475	200	2.07E-04	23.1	-1.1
PBE01C	2.5	5475	25	2.09E-04	22.9	-2.3
PBE01C	2.5	5475	50	1.98E-04	23.2	-2.6
PBE01C	2.5	5475	100	1.61E-04	21.4	-2.0
PBE01C	2.5	5475	200	1.20E-04	22.1	-3.5
PBE02B	2.5	5475	800	8.04E-05	23.0	3.2
PBE02B	2.5	5475	100	1.98E-04	13.7	2.0
PBE02B	2.5	5475	200	1.89E-04	17.4	0.5
PBE03B	2.5	5475	100	1.55E-04	18.5	10.7
PBE03B	2.5	5475	200	2.19E-04	22.8	8.0
PBE04B	2.5	5475	100	1.98E-04	22.4	8.9
PBE04B	2.5	5475	200	1.63E-04	17.1	12.9
PBE05B	2.5	5475	100	1.73E-04	17.3	9.1
PBE05B	2.5	5475	200	1.33E-04	15.1	10.6
PBD01B	2.7	5460	50	2.47E-04	18.3	8.4
PBD01B	2.7	5460	100	2.99E-04	18.7	7.1
PBD02A	2.1	5460	50	2.04E-04	19.1	-4.6
PBD02A	2.1	5460	100	2.80E-03	21.6	4.9
PBD03B	2.6	5460	50	2.76E-03	21.5	7.2
PBD03B	2.6	5460	25	2.09E-03	21.5	3.0
PBD03B	2.6	5460	100	2.53E-03	20.3	6.4
PBD03B	2.6	5460	200	2.38E-03	20.2	-1.3
PBD03B	2.6	5460	400	2.80E-03	19.2	9.8
PBD03D	2.6	5460	800	2.76E-03	21.1	4.7
PBD04A	2.4	5460	100	2.73E-03	21.0	11.3
PBD04A	2.4	5460	200	2.63E-03	21.4	3.0
PBD04A	2.6	5460	400	1.19E-03	22.5	5.4
PBD04A	2.4	5460	800	4.75E-03	22.1	-25.2
PBD04A	2.4	5460	0	1.74E-04	14.4	-4.9
PBD04A	2.4	5460	50	1.82E-03	14.9	12.1

SITE	DENS	ELEV	TREAT	EMU	INC	DEC
PBD04A	2.4	5460	100	2.73E-03	21.5	19.6
PBD05A	2.2	5460	0	2.61E-03	16.4	11.9
PBD05A	2.2	5460	50	2.65E-03	17.9	12.4
PBD05A	2.2	5460	100	2.45E-03	16.7	8.9
PBD06A	2.5	5460	50	2.67E-03	17.0	14.0
PBD06A	2.5	5460	100	2.66E-03	17.0	13.4
PBD06A	2.5	5460	200	2.55E-03	16.6	12.4
PBC01B	2.8	5450	0	2.06E-03	355.6	54.2
PBC01B	2.8	5450	25	2.01E-03	352.5	53.9
PBC01B	2.8	5450	50	1.99E-03	351.4	53.8
PBC01B	2.8	5450	100	1.81E-03	350.2	51.1
PBC01B	2.8	5450	200	1.41E-03	346.5	50.3
PBC01B	2.8	5450	800	6.01E-04	350.6	50.2
PBC02B	2.8	5450	100	1.99E-04	304.8	43.8
PBC02B	2.8	5450	200	1.72E-03	6.2	22.2
PBC02B	2.7	5450	100	1.45E-03	2.7	41.2
PBC02B	2.7	5450	200	9.39E-04	358.8	38.9
PBC03B	2.7	5450	100	2.52E-03	313.7	48.9
PBC03B	2.7	5450	200	2.22E-03	312.4	51.5
PBC04B	2.6	5450	100	1.66E-03	312.7	50.5
PBC04B	2.6	5450	200	1.33E-03	11.2	33.3
PBC04B	2.6	5450	100	1.13E-03	8.2	32.1
PBC04B	2.6	5450	200	8.85E-04	7.9	28.1
PBC05B	3.0	5450	100	1.03E-03	33.5	7.6
PBC05B	3.0	5450	200	1.44E-03	359.1	57.9
PBC05B	3.0	5450	100	1.48E-03	356.9	56.9
PBB01A	2.9	5430	200	5.60E-03	128.6	80.7
PBB01A	2.9	5430	100	6.60E-05	340.6	62.2
PBB01A	2.9	5430	200	1.19E-03	340.1	62.2
PBB01A	2.9	5430	400	4.07E-04	184.7	84.8
PBB01A	2.9	5430	600	9.5E-04	189.2	62.5
PBB02A	2.9	5430	100	6.01E-02	307.7	36.4
PBB02A	2.9	5430	200	5.27E-03	306.4	61.0
PBB02A	2.9	5430	400	1.17E-03	321.5	77.5
PBB02A	2.9	5430	600	3.15E-04	283.0	79.3
PBB02B	2.8	5430	100	1.73E-04	268.7	67.1
PBB02B	2.9	5430	200	1.03E-02	55.9	55.8
PBB02B	2.8	5430	400	1.10E-02	147.2	-4.6
PBB02B	2.8	5430	600	2.88E-03	149.1	7.2
PBB02B	2.8	5430	100	1.17E-03	154.7	43.1
PBB02B	2.8	5430	200	1.61E-04	214.0	69.0
PBB03A	2.8	5430	400	9.57E-05	290.2	61.2
PBB03A	2.9	5430	600	6.60E-05	92.9	57.8
PBB03A	2.9	5430	800	6.65E-03	314.7	46.7
PBB03A	2.9	5430	100	2.97E-03	313.0	53.7
PBB03A	2.9	5430	200	1.05E-02	306.1	56.9
PBB03A	2.9	5430	400	1.05E-02	304.8	56.0
PBB04A	2.9	5430	600	4.25E-04	302.5	53.0
PBB04A	2.8	5430	100	4.12E-02	96.0	-31.1
PBB04A	2.8	5430	400	9.56E-04	60.9	-11.1
PBB04A	2.8	5430	600	2.99E-04	358.8	65.2
PBB04A	2.8	5430	400	1.56E-04	325.4	43.9
PBB05A	2.8	5430	600	1.75E-04	254.3	76.2
PBB05A	2.8	5430		6.14E-03	20.8	55.8

SITE	DENS	ELEV	TREAT	EMU	INC	DEC
PBB05A	2.8	5430	25	4.99E-03	15.7	59.4
PBB05A	2.8	5430	50	3.70E-03	5.3	61.9
PBB05A	2.8	5430	100	1.74E-04	348.9	63.7
PBB05A	2.8	5430	200	7.08E-04	334.7	63.7
PBB05A	2.8	5430	400	7.61E-05	321.3	60.1
PBB05A	2.8	5430	800	7.18E-03	41.3	62.4
PBB05B	2.9	5430	0	6.28E-03	352.3	63.1
PBB05B	2.9	5430	400	3.49E-04	313.2	55.4
PBB05B	2.9	5430	600	2.25E-04	299.2	45.3
PBB05B	2.8	5420	0	6.32E-03	356.6	55.3
PBA01A	2.8	5420	50	4.75E-03	6.9	51.0
PBA01A	2.8	5420	100	3.72E-04	1.9	43.9
PBA02A	2.8	5420	50	6.24E-03	201.6	47.7
PBA02A	2.8	5420	100	5.37E-03	190.0	50.8
PBA03C	2.8	5420	25	7.76E-03	185.3	47.3
PBA03C	2.8	5420	50	6.72E-03	15.2	54.4
PBA03C	2.8	5420	100	2.80E-03	1.9	58.7
PBA03C	2.8	5420	200	6.66E-02	357.1	57.4
PBA03C	2.8	5420	400	2.72E-04	331.4	3.3
PBA03C	2.8	5420	800	1.19E-04	356.0	51.7
PBA04A	2.8	5420	50	5.18E-03	20.3	62.0
PBA04A	2.8	5420	100	1.06E-03	2.2	54.5
PBA05A	2.8	5420	50	5.99E-03	351.1	57.3
PBA05A	2.8	5420	100	4.94E-03	22.9	52.9
PBA05A	2.8	5420	200	2.08E-03	6.1	52.9
PBX01A	2.9	5385	50	1.99E-03	184.9	-73.8
PBX01A	2.9	5385	100	3.02E-03	214.9	-53.0
PBX01A	2.9	5385	200	8.49E-05	211.2	-8.3
PBX01A	2.9	5385	0	3.82E-03	224.5	-21.2
PBX01C	2.9	5385	25	3.23E-04	199.9	-33.4
PBX01C	2.9	5385	50	7.42E-04	209.4	-40.2
PBX01C	2.9	5385	100	7.70E-05	202.6	-16.9
PBX01C	2.9	5385	200	1.13E-04	204.6	10.5
PBX01C	2.9	5385	400	2.09E-03	236.2	50.4
PBX02A	2.9	5385	0	2.09E-03	90.4	-17.6
PBX02A	2.9	5385	50	1.43E-03	85.4	-66.6
PBX02A	2.9	5385	100	1.68E-04	47.3	-82.9
PBX02A	2.9	5385	200	1.68E-05	25.1	-76.9
PBX02B	2.9	5385	100	3.83E-03	124.4	-53.1
PBX02B	2.9	5385	50	1.35E-03	93.2	-56.8
PBX02B	2.9	5385	100	7.35E-05	85.2	-69.7
PBX03A	2.8	5385	50	3.28E-03	316.7	-58.9
PBX03A	2.8	5385	100	7.35E-05	304.6	61.1
PBX03A	2.8	5385	200	3.28E-03	169.7	-74.6
PBX03A	2.8	5385	50	1.59E-03	169.2	-81.1
PBX03A	2.8	5385	100	1.97E-04	176.6	-85.9
PBX04B	2.9	5385	200	5.46E-03	244.1	-75.8
PBW01B	2.9	5385	50	1.17E-03	152.7	-68.2
PBW01B	2.9	5385	0	1.54E-04	215.1	-79.7
PBX04B	2.9	5385	100	1.54E-04	279.2	-39.6

SITE	DENS	ELEV	TREAT	EMU	INC	DEC
PBX04B	2.9	5385	200	4.73E-05	258.0	-27.3
PBX05B	2.9	5385	0	4.53E-03	168.9	74.5
PBX05B	2.9	5385	50	1.17E-03	207.5	-77.0
PBX05B	2.9	5385	100	1.61E-04	250.9	-56.4
PBX05B	2.9	5385	200	5.27E-05	252.3	-56.8
PBU01C	2.6	5220	0	4.69E-04	353.1	44.6
PBU01C	2.6	5220	50	1.79E-04	345.2	59.0
PBU01C	2.6	5220	100	9.17E-05	343.9	64.0
PBU01C	2.6	5220	200	1.53E-05	333.9	62.1
PBU01C	2.6	5220	400	1.14E-05	31.6	84.6
PBU02C	2.7	5220	800	4.51E-04	91.2	66.9
PBU02C	2.7	5220	50	1.86E-04	321.5	63.6
PBU02C	2.7	5220	100	4.51E-04	337.8	66.7
PBU02C	2.7	5220	200	5.09E-05	343.0	67.5
PBU02C	2.7	5220	400	2.58E-05	351.7	69.7
PBU02C	2.6	5220	800	9.37E-06	9.2	57.7
PBU03B	2.6	5220	50	2.98E-04	61.8	41.2
PBU03B	2.6	5220	100	1.37E-04	43.3	51.8
PBU03B	2.6	5220	200	7.40E-05	16.0	58.7
PBU03B	2.6	5220	400	3.51E-05	331.9	71.7
PBU04B	2.7	5220	0	1.25E-05	262.9	85.9
PBU04B	2.7	5220	25	4.45E-04	199.6	50.5
PBU04B	2.7	5220	50	1.83E-04	268.8	82.0
PBU04B	2.7	5220	100	1.43E-04	304.0	82.0
PBU04B	2.7	5220	200	3.68E-05	322.2	76.2
PBU04B	2.7	5220	400	1.82E-05	308.6	76.2
PBU04B	2.7	5220	800	2.59E-06	108.0	53.0
PBU05A	2.6	5220	0	4.68E-04	263.2	43.4
PBU05A	2.6	5220	50	2.00E-04	79.9	1.4
PBU05A	2.6	5220	100	8.46E-05	43.7	78.3
PBU05A	2.6	5220	200	4.20E-05	17.3	81.5
PBV01A	2.2	5100	400	1.20E-05	226.2	84.5
PBV01A	2.2	5100	0	2.96E-04	109.8	81.8
PBV01A	2.3	5100	100	7.87E-06	5.5	76.1
PBV02A	2.3	5100	200	3.96E-06	6.8	57.5
PBV02A	2.3	5100	0	2.90E-04	138.2	60.7
PBV02A	2.2	5100	100	5.34E-05	1.1	-23.5
PBV03B	2.2	5100	200	1.70E-04	0.5	-63.8
PBV03B	2.2	5100	400	4.87E-04	68.8	71.2
PBV03B	2.2	5100	600	4.43E-04	12.6	18.1
PBV04A	2.2	5100	0	3.56E-04	8.2	64.9
PBV04A	2.2	5100	200	9.83E-05	7.1	65.9
PBV04A	2.2	5100	400	2.47E-04	346.1	66.9
PBV05A	2.2	5100	600	5.02E-05	15.8	72.4
PBV05A	2.3	5100	0	1.36E-04	18.1	60.7
PBV05A	2.3	5100	100	2.57E-04	335.4	61.4
PBW01B	2.3	5100	200	7.66E-05	324.2	27.3
PBW01B	2.4	5000	0	1.81E-05	320.3	56.8
PBW01B	2.4	5000	50	1.04E-04	315.8	51.6
PBW01B	2.4	5000	0	8.32E-05	214.3	24.5
PBW01B	2.4	5000	100	5.21E-05	231.0	85.1

SITE	DENS	ELEV	TREAT	EMU	INC	DEC
PBW01B	2.4	5000	200	2.22E-05	205.4	47.7
PBW02B	2.3	5000	0	1.23E-04	141.0	81.8
PBW02B	2.3	5000	50	1.00E-04	146.5	83.2
PBW02B	2.3	5000	100	5.87E-05	140.6	82.9
PBW02B	2.3	5000	200	1.82E-05	61.3	86.3
PBW03B	2.4	5000	0	1.08E-04	0.1	80.1
PBW03B	2.4	5000	50	8.36E-05	18.8	79.3
PBW03B	2.4	5000	100	8.84E-05	14.0	82.1
PBW03B	2.4	5000	200	1.80E-05	26.0	83.6
PBW04B	2.3	5000	0	1.23E-04	98.0	82.2
PBW04B	2.3	5000	50	9.48E-05	72.1	81.5
PBW04B	2.3	5000	100	5.32E-05	72.1	82.3
PBW05B	2.3	5000	200	1.55E-05	18.7	76.8
PBW05B	2.3	5000	25	1.27E-04	67.6	78.8
PBW05B	2.3	5000	50	1.17E-04	58.9	78.7
PBW05B	2.3	5000	100	6.19E-05	59.8	82.8
PBW05B	2.3	5000	200	2.08E-05	58.1	83.5
PBW05B	2.3	5000	400	7.80E-06	82.4	82.1
PAA01B	2.8	4560	800	1.90E-06	355.2	35.7
PAA01B	2.8	4560	0	1.1BE-03	283.5	-61.2
PAA01C	2.9	4560	400	7.74E-04	208.9	-76.6
PAA01C	2.9	4560	200	1.28E-03	280.8	-54.7
PAA01C	2.9	4560	400	1.76E-03	230.1	-73.6
PAA01C	2.9	4560	600	9.3BE-04	231.2	-77.0
PAA01D	2.9	4560	400	4.44E-04	238.5	-76.2
PAA01D	2.9	4560	600	5.1E-03	309.6	-38.1
PAA01D	2.9	4560	25	1.49E-03	253.3	-59.6
PAA01D	2.9	4560	50	1.52E-03	238.8	-60.2
PAA01D	2.9	4560	100	1.54E-03	230.6	-60.7
PAA02A	2.9	4560	200	9.57E-04	235.2	-47.7
PAA02A	2.9	4560	400	2.06E-04	236.5	-43.8
PAA02A	2.9	4560	800	1.61E-04	200.2	-60.5
PAA02A	2.9	4560	200	2.41E-02	9.7	4.9
PAA02C	2.9	4560	400	1.12E-03	120.4	-61.0
PAA02C	2.9	4560	600	6.35E-04	140.5	-71.5
PAA02C	2.9	4560	0	3.70E-04	163.7	-47.3
PAA03B	2.9	4560	200	2.31E-02	98.5	-2.3
PAA03B	2.9	4560	400	3.59E-03	100.0	-16.1
PAA03B	2.9	4560	600	1.26E-03	100.1	-47.0
PAA03C	2.8	4560	100	5.20E-04	125.5	-58.7
PAA03C	2.8	4560	200	2.56E-04	102.1	-55.3
PAA03C	2.8	4560	400	9.68E-02	98.6	-51.2
PAA04B	2.8	4560	800	5.53E-03	91.8	11.5
PAA03B	2.9	4560	200	5.53E-03	94.2	4.1
PAA03B	2.9	4560	400	5.25E-04	103.2	-5.7
PAA03B	2.9	4560	600	5.25E-04	101.7	-9.6
PAA03C	2.8	4560	100	8.97E-02	90.7	11.6
PAA03C	2.8	4560	200	2.19E-02	90.0	10.7
PAA03C	2.8	4560	400	3.38E-03	93.8	-1.2
PAA04B	2.8	4560	800	2.91E-04	102.1	-26.0
PAA04B	2.9	4560	0	6.91E-03	94.1	-47.5
PAA04B	2.9	4560	400	1.06E-03	257.4	-23.5
PAA04B	2.9	4560			204.5	-70.6

SITE	DENS	ELEV	TREAT	EMU	INC	DEC
PAA04C	2.8	4560	0	6.61E-03	257.4	-20.3
PAA04C	2.8	4560	100	1.90E-03	197.5	-56.7
PAA04C	2.8	4560	200	1.34E-03	196.6	-65.3
PAA04C	2.8	4560	400	1.03E-03	208.6	-70.9
PAA04C	2.8	4560	600	3.49E-04	204.5	-65.2
PAA04C	2.8	4560	800	1.94E-04	166.1	-64.6
PAA05B	2.9	4560	0	1.02E-03	212.0	18.5
PAA05B	2.9	4560	200	1.07E-02	205.1	-25.6
PAA05B	2.9	4560	400	4.73E-04	210.2	-43.0
PAA05C	2.9	4560	600	1.81E-04	195.9	-31.6
PAA05C	2.9	4560	100	1.21E-02	204.6	18.5
PAA05C	2.9	4560	200	2.85E-03	200.4	-21.4
PAA05C	2.9	4560	400	1.09E-03	203.6	-30.5
PAA05C	2.9	4560	800	3.76E-03	211.5	-12.4
PAB01C	2.7	4505	25	6.42E-05	50.2	70.2
PAB01C	2.7	4505	50	2.97E-03	21.2	71.2
PAB01C	2.7	4505	100	2.94E-03	23.1	73.2
PAB01C	2.7	4505	200	2.90E-03	28.8	76.4
PAB01C	2.7	4505	400	1.47E-03	22.6	71.2
PAB01C	2.7	4505	800	1.28E-03	35.8	79.2
PAB02D	2.6	4505	0	5.75E-04	34.7	78.2
PAB02D	2.6	4505	50	5.97E-05	21.5	83.1
PAB02D	2.6	4505	100	6.78E-03	18.7	82.5
PAB02D	2.6	4505	200	6.78E-03	22.0	82.0
PAB02D	2.6	4505	400	4.71E-03	24.8	82.0
PAB02D	2.6	4505	800	3.08E-03	13.4	81.1
PAB02D	2.6	4505	401	3.08E-03	13.3	81.1
PAB02D	2.6	4505	410	2.74E-03	11.2	74.4
PAB02D	2.6	4505	800	1.41E-03	30.1	83.3
PAB03C	2.6	4505	0	2.09E-03	32.9	86.3
PAB03C	2.6	4505	50	2.09E-03	345.1	86.3
PAB03C	2.6	4505	81	2.11E-03	7.7	86.2
PAB03C	2.6	4505	100	1.98E-03	353.6	85.9
PAB03C	2.6	4505	200	1.81E-03	344.1	86.2
PAB03C	2.6	4505	400	1.39E-03	336.2	86.6
PAB04D	2.6	4505	50	1.19E-03	30.5	86.1
PAB04D	2.7	4505	100	6.23E-04	53.2	87.6
PAB04D	2.7	4505	200	1.63E-03	58.7	79.1
PAB04D	2.7	4505	400	1.61E-03	57.0	78.4
PAB04D	2.7	4505	410	1.50E-03	60.3	78.3
PAB04D	2.7	4505	800	1.05E-03	58.3	77.8
PAB05B	2.7	4505	410	1.11E-04	62.4	80.0
PAB05B	2.6	4505	0	8.11E-04	61.5	80.3
PAB05B	2.6	4505	50	7.88E-04	27.8	78.3
PAB05B	2.6	4505	100	7.06E-04	25.6	77.2
PAB05B	2.6	4505	200	5.43E-04	23.3	76.9
PAB05B	2.6	4505	410	3.47E-04	21.5	77.3
PAE01B	2.6	4505	800	3.00E-04	32.3	79.0
PAE01B	2.8	4465	25	1.28E-03	39.5	78.3
PKC01A	2.6	4465	50	5.54E-03	184.8	-65.8

SITE	DENS	ELEV	TREAT	EMU	INC	DEC
PAC01A	2.6	4465	100	5.38E-03	184.6	-68.9
PAC01A	2.6	4465	200	3.84E-03	177.8	-70.9
PAC01B	2.6	4465	25	3.83E-03	223.9	-56.9
PAC01B	2.6	4465	50	3.90E-03	225.5	-57.3
PAC01B	2.6	4465	100	3.90E-03	225.6	-57.6
PAC01B	2.6	4465	200	3.77E-03	223.6	-59.3
PAC01B	2.6	4465	400	3.49E-03	215.9	-63.8
PAC01B	2.6	4465	800	1.77E-03	217.8	-62.2
PAC01B	2.6	4465	200	8.42E-04	221.6	-60.8
PAC02B	2.6	4465	400	8.30E-03	189.7	-68.7
PAC02B	2.6	4465	100	7.65E-03	187.2	-69.8
PAC02B	2.6	4465	200	4.89E-03	186.6	-69.8
PAC03B	2.7	4465	100	1.94E-03	198.5	-60.7
PAC03B	2.7	4465	200	1.73E-03	186.3	-65.1
PAC04B	2.7	4465	100	1.17E-03	187.5	-64.8
PAC04B	2.7	4465	200	6.33E-03	186.5	-63.2
PAC05B	2.7	4465	100	6.20E-03	185.6	-64.6
PAC05B	2.7	4465	200	6.92E-03	187.7	-68.2
PAC05B	2.7	4465	400	5.78E-03	188.7	-68.3
PAD01B	2.7	4440	100	3.71E-03	195.2	-29.0
PAD01B	2.7	4440	200	1.78E-03	189.8	-45.5
PAD01B	2.7	4440	400	1.04E-03	189.9	-47.5
PAD01B	2.7	4440	600	5.17E-04	193.5	-47.1
PAD01B	2.7	4440	800	2.58E-03	199.3	-43.7
PAD03B	2.7	4440	0	1.29E-03	196.4	-44.0
PAD03B	2.7	4440	100	1.84E-02	116.7	-24.5
PAD03B	2.7	4440	200	6.73E-03	117.2	-23.3
PAD03B	2.7	4440	400	2.53E-03	124.4	-14.3
PAD04A	2.7	4440	800	1.04E-03	130.4	-11.2
PAD04A	2.7	4440	0	2.62E-04	134.4	-12.8
PAD04A	2.7	4440	100	3.55E-02	86.7	-55.1
PAD04A	2.7	4440	200	1.59E-02	95.1	-59.9
PAD04A	2.7	4440	400	4.72E-03	106.0	-66.9
PAD04B	2.7	4440	600	1.43E-03	134.3	-67.2
PAD04B	2.7	4440	0	8.85E-04	127.9	-68.0
PAD04B	2.7	4440	25	2.17E-02	131.7	-67.3
PAD04B	2.7	4440	50	1.38E-02	125.1	-67.5
PAD04B	2.7	4440	100	8.64E-03	123.6	-74.5
PAD04B	2.7	4440	200	3.52E-03	135.4	-74.5
PAD04B	2.7	4440	400	1.15E-03	147.8	-72.5
PAD04B	2.7	4440	800	2.41E-04	144.4	-72.5
PAD05B	2.7	4440	1000	1.61E-04	140.0	-75.0
PAD05B	2.4	4440	0	3.79E-03	182.1	-72.9
PAD05B	2.4	4440	100	1.72E-03	184.6	-73.9
PAD05B	2.4	4440	400	1.70E-03	186.4	-73.4
PAD05B	2.4	4440	800	5.72E-04	195.3	-75.1
PAE01B	2.8	4400	25	1.13E-04	242.3	-83.6
PAE01B	2.8	4400	50	1.05E-02	319.4	69.8
PAE01B	2.8	4400	25	1.01E-02	315.7	69.9
PAE01B	2.8	4400	50	9.64E-03	313.7	69.9

SITE	DENS	ELEV	TREAT	EMU	INC	DEC
PAE01B	2.8	4400	100	8.69E-03	312.6	69.0
PAE01B	2.8	4400	200	6.55E-03	311.1	70.1
PAE01B	2.8	4400	400	3.13E-03	308.9	69.9
PAE01B	2.8	4400	800	1.05E-03	303.4	69.5
PAE02C	2.7	4400	0	5.90E-03	325.2	69.5
PAE02C	2.7	4400	100	2.67E-03	317.8	67.1
PAE02C	2.7	4400	200	2.03E-03	315.9	69.8
PAE03B	2.8	4400	0	9.04E-03	310.4	69.8
PAE03B	2.8	4400	100	8.28E-03	308.2	69.8
PAE03B	2.8	4400	200	6.46E-03	308.6	72.5
PAE04B	2.8	4400	100	6.12E-03	320.7	68.9
PAE04B	2.8	4400	200	3.02E-03	309.5	69.4
PAE05B	2.8	4400	100	1.99E-03	308.1	70.7
PAE05B	2.8	4400	200	7.20E-03	324.6	69.3
PAE05B	2.6	4370	100	5.16E-03	316.8	71.5
PAF01A	2.6	4370	200	6.41E-03	49.1	83.6
PAF01A	2.6	4370	100	2.14E-03	297.9	83.7
PAF02B	2.6	4370	200	6.23E-03	281.0	79.0
PAF02B	2.6	4370	100	2.59E-03	308.2	79.0
PAF02B	2.6	4370	200	1.98E-03	317.4	77.6
PAF03A	2.5	4370	100	1.48E-02	297.6	83.3
PAF03A	2.5	4370	200	1.38E-02	243.5	81.8
PAF03A	2.5	4370	100	9.82E-03	263.5	82.6
PAF04A	2.5	4370	200	1.04E-02	245.3	77.6
PAF04A	2.6	4370	100	9.46E-03	325.7	77.3
PAF04A	2.6	4370	200	7.14E-03	325.8	77.2
PAF05B	2.6	4370	100	1.01E-02	326.7	77.2
PAF05B	2.6	4370	200	1.00E-02	241.9	80.7
PAF05B	2.6	4370	25	9.82E-03	251.4	79.7
PAF05B	2.6	4370	50	9.20E-05	249.8	80.1
PAF05B	2.6	4370	100	6.92E-03	247.5	80.1
PAF05B	2.6	4370	200	3.52E-03	251.6	79.6
PAG01B	2.6	4340	400	1.20E-02	263.7	77.6
PAG01B	2.6	4340	800	1.08E-02	286.9	78.8
PAG01B	2.6	4340	0	1.00E-02	289.5	79.8
PAG01B	2.6	4340	50	8.71E-03	277.3	79.7
PAG01B	2.6	4340	100	5.82E-03	304.6	78.0
PAG02B	2.6	4340	200	2.28E-03	270.8	80.2
PAG02B	2.6	4340	400	4.53E-04	263.8	79.0
PAG02B	2.6	4340	800	1.18E-02	258.2	75.2
PAG02B	2.6	4340	100	9.10E-03	260.2	74.6
PAG02B	2.6	4340	200	5.44E-03	233.0	73.9
PAG03B	2.7	4340	100	5.96E-03	329.6	78.8
PAG03B	2.7	4340	200	2.65E-03	299.7	69.5
PAG03B	2.7	4340	100	1.64E-03	300.9	77.5
PAG04A	2.7	4340	200	5.14E-03	296.7	76.7
PAG04A	2.7	4340	100	1.56E-03	289.5	84.3
PAG04A	2.7	4340	200	9.74E-04	282.5	79.1
PAG05B	2.7	4340	100	1.48E-03	293.0	73.8
PAG05B	2.7	4340	200	9.74E-03	286.2	74.1
PAG05B	2.7	4340	200	6.19E-03	285.8	74.8

SITE	DENS	ELEV	TREAT	EMU	INC	DEC
PAH01B	2.7	4300	0	7.37E-03	16.7	68.9
PAH01B	2.7	4300	25	5.55E-03	13.5	68.4
PAH01B	2.7	4300	50	3.64E-03	18.9	69.1
PAH01B	2.7	4300	100	2.94E-03	17.5	68.1
PAH01B	2.7	4300	200	1.65E-03	19.7	68.6
PAH01B	2.7	4300	400	5.72E-04	26.9	69.2
PAH01B	2.7	4300	800	1.57E-04	22.0	60.3
PAH02B	2.4	4300	100	6.74E-03	17.7	63.6
PAH02B	2.4	4300	100	1.90E-03	20.9	65.6
PAH02B	2.4	4300	200	1.85E-03	21.1	66.3
PAH03B	2.3	4300	100	7.32E-03	17.6	61.2
PAH03B	2.3	4300	200	1.61E-03	23.1	62.8
PAH04B	2.7	4300	100	9.12E-04	20.2	61.6
PAH04B	2.7	4300	200	9.21E-04	1.2	67.2
PAH05A	2.7	4300	100	8.11E-03	1.5	66.5
PAH05A	2.7	4300	200	7.76E-03	3.0	66.5
PAH05A	2.7	4300	200	3.43E-03	10.3	72.5
PAI01C	2.7	4230	100	1.30E-03	14.3	69.8
PAI01C	2.7	4230	200	1.06E-03	323.4	62.5
PAI01C	2.7	4230		8.36E-04	344.8	76.8
PAI01C	2.7	4230	25	7.45E-04	23.8	82.0
PAI01C	2.7	4230	50	5.14E-04	35.5	84.0
PAI01C	2.7	4230	100	8.22E-04	44.9	85.0
PAI01C	2.7	4230	400	1.36E-04	21.2	85.0
PAI01C	2.7	4230	800	4.27E-05	176.5	82.1
PAI02C	2.7	4230	100	1.05E-03	34.8	78.6
PAI02C	2.7	4230	25	4.77E-04	53.6	81.5
PAI02C	2.7	4230	50	2.52E-04	55.0	82.1
PAI02C	2.7	4230	100	1.24E-03	259.6	82.6
PAI03A	2.7	4230	100	5.61E-04	47.9	87.8
PAI03A	2.7	4230	200	3.55E-04	36.5	87.4
PAI04C	2.7	4230	100	3.46E-03	60.5	87.6
PAI04C	2.7	4230	200	3.19E-03	82.0	88.0
PAI04C	2.7	4230	100	2.43E-03	78.4	88.2
PAI05B	2.7	4230	200	3.36E-03	110.1	85.8
PAJ05B	2.7	4230	100	3.10E-03	104.2	85.3
PAJ05B	2.7	4230	200	2.38E-03	114.2	85.9
PAJ01A	2.9	4200	100	1.1BE-03	281.9	7.6
PAJ01A	2.9	4200	200	6.26E-03	304.1	72.2
PAJ01A	2.9	4200	100	2.77E-03	301.0	75.3
PAJ02A	2.8	4200	200	9.73E-04	314.4	67.9
PAJ02A	2.8	4200	100	9.56E-03	306.4	76.3
PAJ02A	2.5	4200	200	4.39E-04	288.9	80.2
PAJ03B	2.5	4200	100	4.3BE-03	336.3	80.6
PAJ03B	2.5	4200	200	2.35E-03	342.8	80.3
PAJ04A	2.7	4200	100	9.39E-03	338.4	81.8
PAJ04A	2.7	4200	200	9.39E-03	300.8	80.2
PAJ04A	2.7	4200	100	2.14E-03	299.4	80.2
PAJ05B	2.7	4200	200	7.51E-03	333.4	78.5
PAJ05B	2.7	4200	100	3.99E-03	332.5	79.2
PAK01A	2.9	4170	200	2.24E-03	332.3	79.9
PAK01A	2.9	4170	0	9.65E-03	305.6	75.3

SITE	DENS	ELEV	TREAT	EMU	INC	DEC
PAK01A	2.9	4170	100	2.90E-03	300.9	78.8
PAK01A	2.9	4170	200	1.35E-03	298.1	79.2
PAK02A	2.8	4170	0	1.27E-02	307.3	82.1
PAK02A	2.8	4170	100	5.57E-03	306.0	81.5
PAK02A	2.8	4170	200	2.64E-03	309.0	80.7
PAK03B	2.8	4170	25	7.31E-03	324.1	77.0
PAK03B	2.8	4170	50	6.93E-03	322.0	77.2
PAK03B	2.8	4170	100	6.52E-03	318.0	78.9
PAK03B	2.8	4170	200	5.59E-03	322.2	76.6
PAK03B	2.8	4170	400	3.57E-03	319.3	77.3
PAK03B	2.8	4170	800	2.03E-03	316.0	77.8
PAK04A	2.8	4170	100	9.22E-04	330.2	73.5
PAK04A	2.8	4170	200	5.42E-04	0.2	75.7
PAR04A	2.8	4170	100	2.25E-04	12.0	76.0
PAR05A	2.9	4155	200	8.25E-04	17.2	76.3
PAR05A	2.9	4155	100	2.61E-03	104.3	81.5
PAL01B	2.9	4155	200	1.07E-03	139.4	81.6
PAL01B	3.0	4155		7.84E-04	276.1	67.6
PAL02B	3.0	4155	100	8.8BE-05	287.9	67.3
PAL02B	3.0	4155	200	1.02E-03	307.9	62.8
PAL02B	3.0	4155		4.43E-04	281.9	80.0
PAL02B	3.0	4155	25	1.39E-04	303.1	79.5
PAL02B	3.0	4155	50	7.57E-05	313.3	74.7
PAL02B	2.9	4155	100	1.34E-05	315.3	68.6
PAL03B	2.9	4155	400	9.46E-04	302.2	71.2
PAL03B	2.9	4155	800	7.11E-05	305.1	67.1
PAL03B	2.9	4155	100	5.79E-04	351.6	31.2
PAL04B	2.9	4155	200	1.50E-04	321.3	68.5
PAL04B	2.9	4155	100	9.29E-05	330.3	69.1
PAL04B	2.9	4155	200	8.18E-04	264.9	60.2
PAL05C	2.9	4155	100	1.37E-04	298.5	61.5
PAL05C	2.7	4135	200	8.57E-04	299.5	73.8
PAL05C	2.7	4135	100	1.51E-03	297.8	75.7
PAM01B	2.7	4135	200	1.48E-03	318.9	79.6
PAM01B	2.7	4135	100	1.03E-03	317.8	69.2
PAM02B	2.7	4135	200	4.13E-04	165.2	62.2
PAM02B	2.7	4135	100	1.5BE-04	167.3	-38.8
PAM02B	2.7	4135	200	2.65E-04	129.9	-38.1
PAM02B	2.7	4135		2.37E-04	167.3	-38.9
PAM02B	2.7	4135	100	1.56E-04	344.9	33.0
PAM03C	2.8	4135	200	1.53E-04	129.2	67.9
PAM03C	2.8	4135	100	5.07E-04	146.1	-37.7
PAM04C	2.8	4135	200	4.47E-04	111.2	30.6
PAM04C	2.8	4135	100	2.81E-04	158.8	-46.3
PAM04C	2.8	4135	200	1.56E-03	160.2	-47.9
PAM05B	2.8	4135	100	1.52E-03	160.4	-50.1
PAM05B	2.7	4135	200	1.06E-03	162.8	-51.8
PAM05B	2.7	4135	0	6.87E-04	70.4	11.2

SITE	DENS	ELEV	TREAT	EMU	INC	DEC
PAM05B	2.7	4135	100	2.77E-04	155.8	-32.2
PAM05B	2.7	4135	200	1.48E-04	160.3	-39.4
PAN01B	2.9	4125	0	2.50E-04	206.9	7.5
PAN01B	2.9	4125	100	2.71E-04	165.3	-32.6
PAN01B	2.8	4125	200	1.23E-04	168.6	-33.0
PAN02C	2.8	4125	100	4.62E-04	187.3	-3.1
PAN02C	2.8	4125	200	4.92E-04	172.7	-47.7
PAN02C	2.8	4125	100	3.04E-04	173.0	-49.3
PAN03B	2.8	4125	100	1.47E-04	130.9	-14.8
PAN03B	2.8	4125	200	2.73E-04	152.2	-40.3
PAN03B	2.8	4125	100	2.35E-04	158.2	-46.9
PAN04B	2.7	4125	100	2.07E-04	149.5	-12.6
PAN04B	2.7	4125	200	4.63E-04	185.4	-42.7
PAN04B	2.7	4125	100	2.37E-04	183.8	-44.5
PAN05C	2.9	4125	200	3.50E-04	87.4	-33.6
PAN05C	2.9	4125	25	3.55E-04	139.1	-51.4
PAN05C	2.9	4125	50	2.83E-04	152.0	-52.8
PAN05C	2.9	4125	200	1.76E-04	161.6	-55.5
PAN05C	2.9	4125	400	7.29E-05	152.1	-50.7
PAO01C	2.9	4125	800	4.16E-05	229.3	-37.0
PAO01C	2.9	4115		3.38E-03	181.3	-75.9
PAO01C	2.9	4115	100	1.68E-03	175.1	-74.6
PAO01C	2.9	4115	200	5.28E-03	178.9	-73.2
PAO02C	2.8	4115	100	3.43E-03	162.9	-77.5
PAO02C	2.8	4115	200	2.65E-03	166.9	-75.3
PAO02C	2.8	4115		1.28E-03	163.9	-75.8
PAO03C	2.8	4115	100	6.81E-03	165.6	-74.7
PAO03C	2.8	4115	200	4.53E-03	166.8	-74.4
PAO03C	2.8	4115	100	1.58E-03	171.8	-74.2
PAO04A	2.8	4115	200	4.03E-03	296.2	-23.3
PAO04A	2.8	4115	100	3.36E-03	295.4	-22.8
PAO04A	2.8	4115	200	1.60E-03	295.4	-23.1
PAO05B	2.6	4115		9.30E-05	184.4	10.4
PAO05B	2.6	4115	25	2.62E-04	154.7	-74.9
PAO05B	2.6	4115	50	2.60E-04	161.2	-76.1
PAO05B	2.6	4115	100	1.31E-04	159.1	-75.5
PAO05B	2.6	4115	200	5.30E-05	174.3	-67.8
PAO05B	2.6	4115	400	1.72E-05	178.1	-71.8
PAP01B	2.6	4100	800	1.05E-05	128.5	-29.5
PAP01B	2.6	4100	100	6.43E-04	227.0	-42.0
PAP01B	2.6	4100	200	1.27E-04	163.9	-75.7
PAP02B	2.6	4100	100	2.26E-04	158.3	-75.7
PAP02B	2.6	4100	200	1.84E-04	153.2	-86.8
PAP03B	2.6	4100	100	8.97E-05	121.9	-85.0
PAP03B	2.8	4100	200	3.09E-04	344.5	-20.3
PAP03B	2.8	4100	100	1.50E-04	357.3	-75.1
PAP04B	2.8	4100	200	8.75E-05	358.8	-83.7
PAP04B	2.7	4100	100	2.37E-04	276.2	-38.7
PAP04B	2.7	4100	200	1.48E-04	266.4	-77.4
PAP05B	2.7	4100	100	1.01E-04	250.8	-79.5
PAP05B	2.5	4100	200	1.47E-03	305.2	-35.7
PAP05B	2.5	4100	25	8.79E-04	259.9	-78.3

SITE	DENS	ELEV	TREAT	EMU	INC	DEC
PAP05B	2.5	4100	50	7.84E-04	194.6	-83.3
PAP05B	2.5	4100	100	4.52E-04	170.0	-80.7
PAP05B	2.5	4100	200	1.81E-04	165.6	-75.0
PAP05B	2.5	4100	400	4.34E-05	173.9	-62.9
PAP05B	2.5	4100	800	2.36E-05	207.3	48.1
PAQ01A	2.8	4065	0	2.77E-03	319.5	57.1
PAQ01A	2.8	4065	100	8.45E-04	331.2	59.7
PAQ01A	2.8	4065	200	3.79E-04	341.3	58.6
PAQ02A	2.8	4065	100	2.68E-03	325.4	61.6
PAQ02A	2.7	4065	200	1.10E-03	332.9	62.0
PAQ02A	2.7	4065	0	5.47E-04	346.7	61.1
PAQ03B	2.6	4065	100	3.70E-03	311.9	41.4
PAQ03B	2.6	4065	200	3.77E-03	333.8	58.1
PAQ03B	2.6	4065	0	2.73E-03	349.5	63.4
PAQ04B	2.6	4065	100	2.12E-03	332.9	46.4
PAQ04B	2.6	4065	200	1.52E-03	344.7	55.6
PAQ05C	2.6	4065	0	9.82E-04	353.3	59.8
PAQ05C	2.8	4065	50	2.62E-03	347.2	40.7
PAQ05C	2.8	4065	100	2.06E-03	345.9	42.8
PAQ05C	2.8	4065	200	1.91E-04	347.3	46.0
PAQ05C	2.8	4065	400	1.67E-03	353.1	54.2
PAQ05C	2.8	4065	800	1.06E-03	358.5	60.2
PAR01B	2.9	4030	400	3.55E-04	1.6	59.3
PAR01B	2.9	4030	800	5.75E-04	34.5	67.2
PAR01B	2.9	4030	100	1.44E-03	37.0	55.5
PAR01B	2.9	4030	200	5.17E-04	46.1	54.4
PAR01B	2.9	4030	400	3.21E-04	48.1	54.1
PAR02B	2.9	4030	100	1.12E-04	48.9	42.6
PAR02B	2.8	4030	200	2.25E-03	146.9	80.8
PAR02B	2.9	4030	400	5.11E-04	153.6	82.2
PAR02B	2.9	4030	100	2.94E-04	283.3	59.8
PAR03B	2.9	4030	200	1.39E-04	302.6	65.0
PAR03B	2.9	4030	400	9.11E-04	31.5	61.8
PAR03B	2.9	4030	0	6.00E-04	44.0	60.5
PAR04B	2.8	4030	100	1.15E-03	42.9	76.4
PAR04B	2.8	4030	0	7.03E-04	71.9	56.6
PAR04B	2.8	4030	100	4.90E-04	43.9	57.6
PAR05B	3.0	4030	0	1.65E-03	50.3	68.0
PAR05B	3.0	4030	25	1.42E-03	49.7	65.0
PAR05B	3.0	4030	50	1.31E-03	47.4	62.3
PAR05B	3.0	4030	100	1.18E-03	46.6	61.0
PAR05B	3.0	4030	200	9.27E-04	46.1	58.8
PAR05B	3.0	4030	400	8.24E-04	41.7	60.5
PAR05B	3.0	4030	800	8.61E-05	110.8	36.5
PAS01B	2.9	3880	0	1.94E-03	345.3	67.1
PAS01B	2.9	3880	50	8.00E-04	18.1	67.7
PAS01B	2.9	3880	100	4.17E-04	21.6	66.6
PAS01B	2.9	3880	200	2.24E-04	24.4	71.5
PAS02A	2.7	3880	0	6.81E-04	14.3	69.0
PAS02A	2.7	3880	50	5.16E-04	19.0	69.4
PAS02A	2.7	3880	100	4.12E-04	20.7	69.8
PAS02A	2.7	3880	200	2.96E-04	29.0	67.0
PAS03A	2.7	3880	0	1.91E-03	29.0	67.0

SITE	DENS	ELEV	TREAT	EMU	INC	DEC
PAS03A	2.7	3880	50	1.44E-03	27.3	66.5
PAS03A	2.7	3880	100	1.13E-03	29.1	65.7
PAS03A	2.7	3880	200	7.45E-04	25.6	64.9
PAS04B	2.9	3880	0	1.39E-03	21.1	78.0
PAS04B	2.9	3880	25	1.25E-03	13.0	75.5
PAS04B	2.9	3880	50	1.16E-03	10.0	74.6
PAS04B	2.9	3880	100	1.04E-03	8.3	74.9
PAS04B	2.9	3880	200	9.21E-04	346.6	75.1
PAS04B	2.9	3880	400	3.90E-04	315.7	9.4
PAS04B	2.9	3880	800	2.16E-04	78.4	-64.8
PAS05B	2.8	3880	0	4.61E-02	119.6	3.6
PAS05B	2.8	3880	50	3.77E-02	119.2	2.8
PAS05B	2.8	3880	100	2.44E-02	118.9	3.1
PAS05B	2.8	3880	200	7.96E-03	114.5	6.5
PAS05B	2.8	3880	400	1.07E-02	98.5	31.7
PAS05B	2.8	3880	800	3.52E-04	76.1	52.1
PAS05C	2.7	3880	50	9.31E-03	152.4	-11.5
PAS05C	2.7	3880	100	8.19E-02	152.4	-11.5
PAS05C	2.7	3880	200	5.88E-02	152.0	-12.2
PAS05C	2.7	3880	400	2.04E-03	150.8	-11.6
PAS05C	2.7	3880	800	2.90E-04	143.0	-3.9
PAT01B	2.7	3860	100	9.73E-05	118.0	-81.1
PAT01B	2.7	3860	200	1.57E-04	134.0	-10.0
PAT01B	2.7	3860	400	1.43E-04	164.9	-56.2
PAT01B	2.7	3860	800	9.46E-05	164.9	-59.0
PAT02B	2.5	3860	0	4.12E-05	158.7	-59.8
PAT02B	2.5	3860	100	1.06E-03	158.9	-50.9
PAT02B	2.5	3860	200	1.11E-03	169.9	-51.6
PAT02B	2.5	3860	400	1.02E-03	160.1	-52.9
PAT03A	2.7	3860	800	8.32E-04	159.5	-53.0
PAT03A	2.7	3860	0	6.30E-04	161.7	-54.3
PAT03A	2.7	3860	100	7.14E-05	248.0	-63.0
PAT03A	2.7	3860	200	7.11E-04	248.1	-63.4
PAT03A	2.7	3860	400	6.45E-04	246.6	-63.4
PAT04B	1.8	3860	800	3.84E-05	279.5	-79.0
PAT04B	1.8	3860	100	2.65E-05	253.0	-73.3
PAT04B	1.8	3860	200	5.12E-05	339.0	-11.3
PAT04B	1.8	3860	400	5.59E-05	338.5	-20.6
PAT04B	1.8	3860	800	5.77E-05	341.9	-17.8
PAT05C	2.3	3860	0	5.18E-05	341.9	-19.5
PAT05C	2.3	3860	25	1.06E-04	39.7	-63.5
PAT05C	2.3	3860	50	1.09E-03	41.1	-61.8
PAT05C	2.3	3860	100	1.15E-03	35.7	-62.4
PAT05C	2.3	3860	200	1.10E-03	27.2	-63.3
PAT05C	2.3	3860	400	1.04E-03	35.8	-63.3
PAT05C	2.3	3860	800	1.12E-03	24.4	-69.1
PAU01A	2.8	3815	100	9.01E-04	37.6	-64.4
PAU01A	2.8	3815	200	7.48E-04	155.3	-57.4
PAU01A	2.7	3815	50	7.37E-04	154.3	-57.3
PAU02A	2.7	3815	100	6.11E-04	155.8	-57.5
PAU02A	2.7	3815	200	1.71E-03	155.8	-57.3
PAU02A	2.7	3815	100	1.68E-03	156.5	-57.5

SITE	DENS	ELEV	TREAT	EMU	INC	DEC
PAU02A	2.7	3815	200	1.69E-03	156.0	-57.4
PAU03B	3.1	3815	0	5.43E-04	144.3	-63.7
PAU03B	3.1	3815	25	5.60E-04	146.4	-61.4
PAU03B	3.1	3815	50	5.61E-04	146.4	-61.5
PAU03B	3.1	3815	100	5.51E-04	147.6	-61.1
PAU03B	3.1	3815	200	3.51E-04	147.6	-61.8
PAU03B	3.1	3815	400	2.15E-04	149.0	-62.1
PAU04B	3.1	3815	800	1.02E-03	133.4	-75.5
PAU04B	2.7	3815	100	9.82E-04	154.7	-62.4
PAU05B	2.7	3815	200	7.75E-04	154.6	-61.4
PAU05B	2.7	3815	100	7.87E-04	160.4	-61.5
PAU05B	2.7	3815	200	7.86E-04	159.7	-65.1
PAV01B	2.8	3780	100	6.91E-04	159.6	-65.0
PAV01B	2.8	3780	200	1.49E-03	176.4	-72.8
PAV01B	2.8	3780	100	1.46E-03	179.7	-72.8
PAV01B	2.8	3780	200	1.34E-03	179.2	-73.3
PAV02B	2.8	3780	0	1.51E-03	200.0	-64.1
PAV02B	2.8	3780	25	1.54E-03	200.7	-65.1
PAV02B	2.8	3780	50	1.54E-03	200.0	-65.2
PAV02B	2.8	3780	100	1.50E-03	200.9	-59.1
PAV02B	2.8	3780	200	9.20E-04	191.8	-68.3
PAV02B	2.8	3780	400	8.16E-04	199.6	-68.3
PAV02B	2.8	3780	800	5.25E-04	196.6	-60.5
PAV03A	2.8	3780	1000	3.42E-04	192.1	-76.1
PAV03A	2.8	3780	100	2.22E-04	213.8	-70.8
PAV04B	2.8	3780	200	2.72E-04	215.1	-72.0
PAV04B	2.8	3780	100	1.75E-04	215.1	-75.9
PAV05B	2.8	3780	200	2.65E-04	152.0	-65.8
PAV05B	2.8	3780	100	2.61E-04	143.3	-65.8
PAW01B	2.8	3780	200	1.67E-04	146.1	-67.9
PAW01B	2.6	3700	25	4.05E-05	186.2	-42.9
PAW01B	2.6	3700	50	4.61E-05	154.2	-73.8
PAW01B	2.6	3700	100	3.45E-04	157.8	-76.9
PAW01B	2.6	3700	200	3.33E-04	357.1	21.1
PAW01B	2.6	3700	400	3.23E-04	359.1	23.3
PAW01B	2.6	3700	800	1.63E-04	2.3	21.5
PAW01B	2.6	3700	100	6.38E-05	5.1	12.0
PAW01B	2.6	3700	200	3.91E-05	331.9	11.4
PAW02A	2.5	3700	400	4.00E-04	339.3	39.1
PAW02A	2.5	3700	25	3.55E-04	343.3	22.4
PAW02A	2.5	3700	50	3.26E-04	350.4	20.9
PAW02A	2.5	3700	100	2.89E-04	353.3	20.2
PAW02A	2.5	3700	200	1.13E-04	1.5	19.9
PAW02A	2.5	3700	400	7.22E-05	343.1	4.7
PAW02A	2.5	3700	800	5.60E-05	335.6	-4.9
PAW02B	2.5	3700	25	3.07E-04	330.3	-17.8
PAW02B	2.5	3700	50	3.06E-04	340.9	5.2
PAW02B	2.5	3700	100	2.42E-04	348.1	18.7
PAW02B	2.5	3700	200	1.20E-04	352.0	24.5
PAW02B	2.5	3700	400	4.23E-05	354.3	60.8

SITE	DENS	ELEV	TREAT	EMU	INC	DEC
PAY04B	2.7	3650	0	3.63E-04	350.7	-65.3
PAY04B	2.7	3650	25	4.12E-04	358.9	-78.5
PAY04B	2.7	3650	50	4.26E-04	357.9	-83.5
PAY04B	2.7	3650	100	3.77E-04	311.3	-87.7
PAY04B	2.7	3650	200	1.90E-04	255.0	-87.8
PAY04B	2.7	3650	400	6.19E-05	145.4	-87.3
PAY04B	2.7	3650	800	1.53E-05	186.7	-55.2
PAY05B	2.7	3650	100	4.96E-04	81.2	-64.5
PAY05B	2.7	3650	200	5.23E-04	93.4	-78.7
PAY05B	2.7	3650	400	2.47E-04	100.7	-79.0
PAY05B	2.7	3650	800	1.12E-04	99.6	-80.2
PAY05B	2.7	3650		1.12E-04	64.3	-81.4

SITE	DENS	ELEV	TREAT	EMU	INC	DEC
PAW02B	2.5	3700	800	3.58E-07	255.3	7.0
PAW03A	2.7	3700	0	3.76E-04	4.9	10.3
PAW03A	2.7	3700	50	3.20E-04	4.3	13.7
PAW03A	2.7	3700	100	2.48E-04	2.9	16.3
PAW04A	2.7	3700	0	1.01E-03	5.3	20.0
PAW04A	2.7	3700	25	7.37E-04	3.4	29.1
PAW04A	2.7	3700	50	5.71E-04	1.6	30.0
PAW04A	2.7	3700	100	2.72E-04	0.3	31.8
PAW04A	2.7	3700	200	8.64E-05	353.1	38.6
PAW04A	2.7	3700	400	3.11E-05	356.4	45.2
PAW04A	2.7	3700	800	1.15E-05	318.5	-17.3
PAW05B	1.8	3700	25	3.59E-04	333.8	37.3
PAW05B	1.8	3700	50	2.52E-04	357.5	30.0
PAW05B	1.8	3700	100	2.37E-04	0.5	24.6
PAW05B	1.8	3700	200	1.75E-04	1.2	19.7
PAW05B	1.8	3700	400	5.46E-05	10.0	21.0
PAW05B	1.8	3700	800	1.87E-05	105.3	6.2
PAX01B	2.7	3675	0	4.07E-05	32.0	-73.6
PAX01B	2.7	3675	50	6.38E-04	105.0	-69.3
PAX01B	2.7	3675	100	6.69E-04	107.5	-83.0
PAX01B	2.7	3675	200	5.85E-04	108.7	-84.6
PAX01B	2.7	3675	400	5.83E-04	107.3	-85.1
PAX02B	2.8	3675	0	1.52E-04	123.4	-84.4
PAX02B	2.8	3675	50	9.64E-04	181.0	-79.5
PAX02B	2.8	3675	100	1.03E-03	160.9	-85.5
PAX02B	2.8	3675	200	7.68E-04	141.6	-86.1
PAX02B	2.8	3675	400	3.88E-04	139.0	-86.2
PAX02B	2.8	3675	800	3.75E-04	240.7	-88.2
PAX03B	2.9	3675	0	1.08E-03	216.9	-82.1
PAX03B	2.9	3675	50	1.16E-03	194.3	-85.1
PAX03B	2.9	3675	100	1.03E-03	179.0	-85.6
PAX04B	2.7	3675	50	5.62E-04	179.7	-86.1
PAX04B	2.7	3675	100	6.37E-04	196.5	-80.0
PAX04B	2.7	3675	200	8.08E-04	186.6	-84.8
PAX04B	2.8	3675	400	5.54E-04	190.5	-66.9
PAX05B	2.8	3675	0	2.01E-04	191.0	-86.2
PAX05B	2.8	3675	25	2.56E-04	140.6	-78.4
PAX05B	2.8	3675	50	4.59E-04	115.5	-86.2
PAX05B	2.8	3675	100	5.08E-04	114.6	-88.5
PAX05B	2.8	3675	200	3.71E-04	112.2	-88.9
PAX05B	2.8	3675	400	1.55E-04	36.2	-49.9
PAX05B	2.8	3675	800	3.38E-05	314.7	-3.8
PAY01B	2.5	3650	100	9.91E-06	261.2	-68.0
PAY01B	2.5	3650	200	1.40E-04	306.7	-89.1
PAY01B	2.5	3650	400	4.06E-04	79.6	-87.7
PAY02A	2.5	3650	100	2.04E-04	106.3	-53.2
PAY02A	2.7	3650	200	3.20E-04	299.0	-84.5
PAY02A	2.7	3650	400	3.10E-04	10.3	-86.3
PAY02A	2.7	3650	800	1.60E-04	324.0	-50.1
PAY03B	2.6	3650	100	3.31E-04	337.3	-82.1
PAY03B	2.6	3650	200	3.18E-04	8.4	-83.8
PAY03B	2.6	3650	400	1.62E-04	27.4	-85.1
PAY03B	2.6	3650	800	5.69E-05	64.3	-85.1
PAY03B	2.6	3650	800	1.89E-05	253.1	-79.9